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EDITORIAL NOTES.

AT the Annual General Meeting of the Geological Society of London, held on Friday, 20th February, 1925, Dr. J. W. Evans was re-elected President for a second year. Sir Thomas Holland was elected a Vice-President in place of Professor W. W. Watts, and Professor J. E. Marr was appointed to the office of Foreign Secretary, vacant by the death of Sir Archibald Geikie. The new members of the Council are Mr. T. Crook, Professor W. G. Fearnsides, Professor W. T. Gordon, Mr. H. W. Monckton, and Dr. A. E. Trueman. The President delivered his annual address, the subject being *Regions of Tension*, evidenced by jointing, normal faulting, dykes, basalt flows, dolerite sills, and alkaline igneous rocks. Tension is either local or regional. The causes of the former were briefly discussed, but chief stress was laid on tension prevailing over extensive regions. In Western Europe and the Atlantic a roughly east-and-west tension prevailed during Mesozoic and especially Kainozoic times, and there was westerly drift of the land-masses, increasing in amount from Central Europe westwards. There was a widening of the distance between Western Europe and the North Atlantic central ridge, with consequent broadening and deepening of the trough between. Similar evolution took place between the central ridge and the American continent, where also there are evidences of Hercynian tension. These changes were accompanied by partial submergence of the marginal rocks and an almost complete submergence of the central ridge, which apparently had been land since Devonian time. The evidence for regional tension in other parts of the world, especially Africa, was then briefly reviewed and the causes which gave rise to regional tension were discussed.

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THE Annual General Meeting of the Geologists' Association was held on 6th February, 1925. Mr. E. E. S. Brown, F.G.S., 22 Wisteria Road, Lewisham, S.E. 13, is the new General Secretary in place of Mr. W. Wright, resigned, while Mr. G. S. Sweeting, F.G.S., becomes Secretary of the Publications Committee. After presenting the Foulerton Award to Mr. A. L. Leach, F.G.S., as already announced, the President, Mr. H. Dewey, F.G.S., delivered an address on "The Mineral Zones of Cornwall", illustrated by lantern slides.

ORIGINAL ARTICLES.

The Chief Heavy Detrital Minerals in the Rocks of the English Midlands.

By W. F. Fleet, M.Sc., A.I.C., F.G.S.

(PLATES IV AND V.)

IN an earlier paper by the writer (1) [1] an account was given of the chief heavy detrital minerals found in the sandstones of the Trias around Birmingham, and it is now intended to amplify that account by including results obtained over a much wider tract, and at the same time to place on record a description of the chief heavy minerals found in sedimentary rocks of other formations in the same district. Residues have been separated from arenaceous deposits of Cambrian, Ordovician, Silurian, Devonian, Carboniferous, "Permian," and Triassic age occurring within an area, roughly triangular in shape, between Shrewsbury, Nuneaton, and Malvern, and including more than a thousand square miles of the English Midlands. The minerals are described with special reference to (*a*) their relative frequency of occurrence, and (*b*) their characteristic appearance in the various beds. They include zircon, tourmaline, rutile, garnet, staurolite, anatase, apatite, magnetite, ilmenite, leucoxene, barytes, sphene, glauconite, calcite, pyroxene, and a few others of much less frequent occurrence which have not yet been fully investigated, but will be referred to when dealing with the beds in which they occur. In general the residues are small in amount and therefore have not been considered quantitatively. The area under notice, although comprising large portions of Warwickshire, Worcestershire, Shropshire, and Staffordshire, is not extensive from a geological point of view, and it has not been possible to collect material from every outcrop of the various formations, but it is hoped that a general idea will be conveyed concerning the more important characteristics of the heavy mineral suites of the Midland rocks.

It remains for these results to be correlated with those of other workers in neighbouring districts before wider generalizations can be attempted. Although it would have been better perhaps to adopt the more logical method of examining each formation in fuller detail over a more extended area, such has not been possible, and it seems undesirable to hold over the results already obtained for an indefinite period, when the data might be usefully considered in connexion with information already recorded by others. The formations are dealt with in ascending order, the Enville and so-called "Permian" rocks lying between the Keele beds and the

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[1] Figures in parentheses refer to the list of works given at the end of the paper.

Trias, being, for purposes of convenience, treated as a separate section.

The Cambrian Rocks.

It was the writer's original intention to examine the shale-bands and quartzites of the unfossiliferous Lickey Cambrian with a view to possible correlation of the beds exposed in the various quarries by comparison of their heavy mineral suites. This aim has, so far, not been achieved, but the results are interesting and are recorded here. These Lickey quartzites are considered, on lithological grounds, to correspond with the lower part of the Nuneaton quartzite (2). Of the latter some of the Middle (Tuttle Hill) and Upper (Camp Hill) beds were sampled, including the Hyolithes limestone. The Hollybush sandstone of Malvern and the Comley sandstone of the Caradoc district, both of which were regarded by Lapworth as equivalent to the Upper quartzite of Nuneaton (4), were also examined. Reference should be made to Lapworth's "Geology of the Birmingham District" (5) and the Coventry Memoir (7) for descriptions of the Midland Cambrian rocks. Samples were collected from the following localities:—

Nos. 1–6. Thin micaceous clayey and quartzose shale-bands between the quartzite beds of the large quarry south of Rednal, No. 1 representing possibly the lowest Cambrian of the Lickey, and the remainder being taken in ascending order over a thickness of about 80 feet.

No. 7. Decomposed thin quartzite bands from a small quarry at the extreme southern end of the Lickey Hills.

No. 8. Shale-band from a small exposure in Leach Green Lane, near Rednal.

Nos. 9–12. Clays and shales from the quarry opposite Rubery Farm.

No. 12*a*. Soft quartzite immediately beneath the Upper Llandovery Sandstone at Rubery.

No. 13. Shale from Tuttle Hill quartzite beds of the large quarry near Nuneaton (M.R.) station.

No. 14. Shale from Camp Hill quartzite immediately below the Hyolithes limestone at Woodlands Quarry, Hartshill.

No. 14*a*. Hyolithes Limestone from Woodlands Quarry.

No. 15. Hard sandstone from the upper part of Camp Hill quartzite, between the Hyolithes limestone and the Stockingford shales, at Woodlands Quarry.

No. 16. Hollybush Sandstone from White-leaved Oak, Malvern.

No. 17. Comley Sandstone from north end of Caer Caradoc, Shropshire.

The occurrence of the various heavy minerals is shown in the subjoined table, the numbers indicating the relative frequency of each mineral, thus: 1, very scarce; 2, scarce; 3, occasional; 4, fairly frequent; 5, frequent; 6, very frequent; 7, fairly abundant; 8, abundant; 9, very abundant; 10, extremely abundant. The minerals enumerated are zircon, tourmaline, rutile, garnet, staurolite, anatase, apatite, magnetite, ilmenite, barytes, sphene, and pyroxene.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	4	4	4	1	–	2	–	5	8	–	–	–
2.	4	4	2	–	–	–	–	7	8	1	–	–
3.	7	1	4	1	–	–	–	9	9	1	–	–
4.	8	7	7	5	–	2	2	8	8	–	–	–
5.	8	5	5	8	–	2	2	9	9	–	–	–
6.	9	4	5	7	–	2	2	9	9	–	–	–
7.	8	7	2	–	–	7	–	4	4	–	–	–
8.	8	7	5	–	–	2	–	9	8	–	–	–
9.	8	7	5	–	–	–	–	9	9	–	–	–
10.	8	5	5	–	–	2	–	9	8	–	–	–
11.	8	7	5	–	–	7	–	8	8	–	–	–
12.	7	6	5	–	–	5	–	9	8	–	–	–
12*a*.	10	8	3	–	–	8	–	5	5	–	–	–
13.	5	4	4	1	–	5	2	8	8	9	–	–
14.	8	5	5	–	–	4	2	10	7	4	–	–
14*a*.	7	4	5	–	–	–	1	9	8	–	–	–
15.	8	5	7	–	–	3	1	9	9	4	–	–
16.	7	4	5	1	–	1	4	4	8	–	–	–
17.	8	5	6	4	–	1	4	10	7	–	–	–

From the table it will be seen that staurolite, sphene, and pyroxene were not found in the samples examined. Staurolite was suspected in the quartzite immediately beneath the Silurian at Rubery (sample 12*a*), and the point is of interest in view of the fact that this mineral was found in the Llandovery sandstone. Several doubtful grains may be sphene. Barytes is scarce in the Lickey Cambrian, but frequent in most of the Nuneaton samples. Zircon, tourmaline, rutile, magnetite, and leucoxenic ilmenite are invariably present, the two latter being more or less dominant. In the Lickey beds garnet was found only in the samples from Rednal Road quarry, increasing in amount in the higher beds of that exposure. The Hollybush sandstone is deficient in garnet, and markedly so in magnetite when compared with the Comley rock. Anatase is usually present, while apatite is locally present in the upper beds of the Rednal Road quarry, and in the Upper Cambrian of other districts.

Barytes is scarce in the Lickey quartzite, but frequent in most of the Nuneaton samples, while calcite was found in the Hyolithes limestone and underlying shales. Glauconite, a "light" mineral, is not usually retained in the heavy concentrates, and its actual abundance in the samples is not therefore shown.

Notes on the Microscopical Appearance of the Minerals.

Before describing the heavy minerals of the Cambrian, it would be better to avoid repetition by referring briefly to the usual appearance of the various grains found in residues from all the formations, since the minerals possess certain general characteristics in regard to size, form, and colour. It will, then, only be necessary to mention deviations from the usual type. For convenience the size of individual grains is given in accordance with the following table :—

Approximate diameter of grain.	
·05–·08 mm.	small.
·08–·12 ,,	medium.
·12–·2 ,,	large.
larger than ·2 ,,	very large.

Zircon occurs generally as small or medium-sized, colourless grains of worn appearance, sometimes quite rounded, but often retaining good crystalline form.

Tourmaline may appear as irregular or rounded grains, or as worn prisms, colourless, or ranging from pale yellow through salmon-pink, tawny, brownish-green to greenish-blue. Medium-sized or rather large grains predominate.

Rutile occurs as foxy-red or amber, worn prismatic grains or well-rounded forms of medium size.

Garnet is usually medium or large in size, and colourless, though a small percentage of salmon-pink grains is generally present. In form it is sub-angular to rounded.

Staurolite is typically medium or rather large in size, and of various shades of yellow. It is rarely of worn appearance, but shows angular or ragged form.

Anatase occurs as small, yellowish or dark, worn detrital grains, of tabular, and less frequently, pyramidal form.

Apatite generally appears as spherical, oval, or much worn prismatic grains, medium in size, and colourless.

Magnetite, medium or rather large in size, has usually a more or less rounded appearance, and in most rocks appears coated with a reddish oxide, probably hematite, very resistant to boiling HCl.

Ilmenite is rarely unaltered, being present as leucoxene, with a white appearance under reflected light.

Barytes occurs as large, dingy, or speckled, irregular or jagged splinters or plates.

Glauconite, when it appears in a residue, is usually of medium or large size and greenish, yellow, or nearly colourless. Oval or irregular forms are the rule.

Calcite, in residues from calcareous sands, conglomerates, and breccias, occurs as irregular and crystalline plates of varying size and shape. It is removable by cold HCl, which has no effect upon the apatite unless perhaps the action be prolonged. In cases where the carbonate is incompletely removed by the cold acid, it is probable that a percentage of $MgCO_3$ is present as dolomite.

Sphene and *Pyroxene*, being infrequent in the Midland sediments, will be described when dealing with the rocks in which they occur.

Notes on the Cambrian Residues.

Zircon. Occasionally pinkish or purple, rarely yellow. A few very large cloudy oval grains up to 0·25 mm. occur in the shales, while in the soft quartzites the grains are very much worn.

Tourmaline. Occasionally full of large inclusions.

Rutile. Large well-shaped yellow prisms occur, and occasional amber or yellow geniculate twins. The grains, like those of anatase, are coated with quartz in the Lickey and Nuneaton rocks.

Garnet. Small and colourless, and angular, sub-angular, or rounded in form.

Anatase. Occurs in quartzite as small or medium, sharp-edged tabular and pyramidal forms of a yellow, steely-blue, or dark colour. Large grains occasionally present with a percentage of worn detrital grains, and fresh aggregates of tabular crystals. In the shales, occurs as well-worn tabular forms, dusky yellow or dark in colour, and frequently only distinguished with difficulty from leucoxene. Small tabular forms occur as outgrowths upon leucoxene or as aggregates entirely replacing that mineral. Frequently encrusted with quartz. One grain of leucoxenic ilmenite with outgrowths of anatase was completely surrounded by quartz.

Apatite. Discoloured grains showing marked corrosion.

Magnetite. Occasionally showing squarish outlines. In sample 14 the grains were frequently surrounded by a transparent coating, presumably quartz.

Barytes. In the Lickey slides only two grains present, these showing good crystal forms, while in the Nuneaton samples the mineral occurs as medium or large irregular, jagged or rhombic cleavage plates with speckled appearance, probably present as cementing material.

Glauconite. Occurs as bright green grains in samples 14, 14*a*, 15, 16, and 17.

Other minerals noticed in the Cambrian include muscovite (abundant as large rounded plates in the shales), microcline (occasional), orthoclase and plagioclase (frequent), and chlorite.

THE ORDOVICIAN ROCKS.

In the extreme north-west of the area a narrow band of Caradocian rocks crops out between Wenlock Edge and the Longmynd, and certain arenaceous beds of this series were examined. Details of the strata are given by Lapworth and Watts (41). The results are uninteresting, but are recorded here to complete the series. Samples were collected as follows:—

No. 1. Greenish sandstone from Soudley quarry, near Church Stretton.

No. 2. Purplish sandstone from same quarry. Both these samples are from the Chatwall and Soudley beds of Lapworth and Watts.

No. 3. Greenish sandstone probably on the same horizon as 1 and 2 from an old quarry on the Bishop's Castle road, 1 mile west-north-west of Wistanstow.

No. 4. Onny shales or uppermost beds of exposed Caradocian from near Cheney Longville (42).

Distribution of Heavy Minerals.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	9	5	8	7	–	4	5	1	8	1	–	–
2.	9	5	8	7	–	1	–	9	8	–	–	–
3.	7	4	5	4	–	1	1	1	7	–	–	–
4.	Occasional grains of Z., G., M., and Il.											

Sample No. 4, containing no appreciable residue, may be neglected. Sphene, pyroxene, and staurolite are absent, while zircon, rutile, garnet, and ilmenite are unusually abundant. The abundance of magnetite in the purplish sandstone, and its scarcity in the adjacent pale-green rocks are noteworthy items. The samples were micaceous, glauconitic, and practically non-calcareous.

Notes on the Minerals.

Rutile. Occasional yellow grains and geniculate twins.

Garnet. Sub-angular to rounded and medium sized.

Ilmenite. Frequently unaltered in the green sandstones.

Sample 1 is noteworthy for the unworn appearance of its rutile, tourmaline, anatase, and apatite, the rutile frequently appearing as clear yellow prisms.

THE SILURIAN ROCKS.

Arenaceous Silurian rocks are infrequent in the district, but the residues obtained from the small patch of Upper Llandovery rocks near the Lickey are of interest. A list of the rocks examined is given below :—

Nos. 1–2.[1] The Upper Llandovery sandstone lying uncomformably on the Cambrian Quartzite and exposed in the Leach Green Lane and Bristol Road quarries at Rubery. No. 1 was taken from the conglomerate band lying immediately upon the Cambrian, No. 2 from several feet higher, and No. 2*a* from the white sandstone about 25 feet above the base of the Silurian. Stratigraphical and other details are given in Professor Lapworth's description (6) and in the *Summary of Progress for* 1920 (2).

No. 3. Similar sandstone from a higher horizon in the recent road-widening at Rubery a little east of Nos. 1 and 2.

No. 3*a*. A thin band of loose clayey sand from near No. 3, lying between grey and purple clays well above the Cambrian.

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[1] Since the above was written the writer has examined samples of the hard grit occurring at Kenley and Church Preen, west of Wenlock Edge, and regarded by Lapworth as Upper Llandovery in age (42). The heavy residue closely resembles those of the Rubery Silurian rocks. Garnet is scarce, staurolite and apatite absent, but fresh sharp-edged anatase forms frequent.

No. 4. Yellowish, dark-banded and fine-grained sandstone resulting from the decalcification of limestone, and containing unaltered fragments of the latter. This bed occurs at a higher horizon than the foregoing.

The heavy minerals are distributed as follows :—

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	8	7	2	–	–	5	–	9	7	–	–	–
2.	9	8	4	2	1	7	–	9	7	–	–	–
2*a*.	8	4	–	–	–	5	–	5	4	–	–	–
3.	7	4	2	–	–	2	–	8	5	–	–	–
3*a*.	5	4	2	–	–	1	–	8	5	1	–	–
4.	7	5	7	2	–	8	4	9	7	1	–	–

As in the Cambrian, zircon, tourmaline, magnetite, and ilmenite are the minerals occurring most frequently. Anatase is frequent, rutile only occasional, and garnet scarce. The recording of staurolite is of interest, the Upper Llandovery being the lowest horizon at which this mineral has been definitely observed by the writer. Sphene and pyroxene are absent, and apatite rare.

Notes on the Minerals.

Zircon. Well-rolled grains, frequently cloudy and discoloured and occasionally pink.

Tourmaline. Rounded and occasionally prismatic. Greenish and bluish grains occur.

Garnet. Small, colourless, angular, or sub-angular forms.

Staurolite. One medium-sized angular grain.

Anatase. Small or medium, occasionally large crystals of yellow, steel-blue or dark colour. Some grains are detrital, but the majority are fresh sharp-edged forms, usually tabular, but sometimes pyramidal in shape. Aggregates of small crystals occur.

Magnetite. Occasionally very large (0·3 mm.).

Ilmenite. Unaltered grains occur.

Muscovite. Appears as medium-sized plates,

Glauconite is occasional, but calcite is absent.

THE DEVONIAN ROCKS.

The Old Red Sandstone crops out along the western part of the district, and there are certain small inliers in South Staffordshire (9, 11, 12, 13, 15). Samples were collected from near Ross, Ledbury, Clee, Saltwells, etc., but it is mainly to Mr. Wickham King that the writer is indebted for assistance in investigating the Devonian beds. Mr. King very kindly supplied a large selection from the Downtonian and Dittonian subdivisions of the Lower Old Red Sandstone or Devonian, together with samples from the Upper Old Red Sandstone. The following is a list of all the beds examined, the height of each above the Ludlow Bone bed of the Silurian being given where known, and according to Mr. King's notes.

Downtonian.

No. 1. Near horizon of Ledbury Fish Zone at Wordley, near Shaver's End, Abberley. 400 ft. above L.B.B.

No. 2. Lower Fish-band of Downtonian from Ledbury Railway cutting. 450 ft.

No. 3. Ledbury Fish Zone, Wordley Brook, Abberley. 450 ft.

No. 4. Holdgate Sandstone, Corve Dale. 900 ft.

No. 5. Trimpley Fish Zone, Man Brook, Trimpley. 1,400 ft.

No. 6. Upper part of Trimpley Fish Zone, Wordley Brook. Netherton Farm. 1,500 ft.

No. 7. Birch Hill Limestone, Shatterford Hill, Trimpley. 1,800 ft.

No. 8. Eastham Sandstone, Shatterford Hill. 1,930 ft.

Dittonian.

No. 9. Cephalaspis Sandstone, Shatterford Hill. 2,060 ft.

No. 10. Guildings Brook Fish zone, Trimpley. 2,200 ft.

No. 11. Hall Barn Cornstones, Trimpley. 2,500 ft.

No. 12. From exposure 1 mile west of Cleobury Mortimer.

No. 13. From Hopton Wafers, Titterstone Clee. (The exact horizons of these two samples are not known.)

Upper Old Red Sandstone.

No. 14. Farlow Sandstone, Brown Clee.

No. 15. Farlow Sandstone, near Farlow Church, Titterstone Clee.

No. 16. Sandstone from Farlow Bank, Clee.

No. 17. Sandstone from Farlow Bank, Clee, above No. 16.

The above, with the exception of Nos. 12, 13, 16, and 17, were supplied by Mr. King. The exact position of the two following in the Devonian series is doubtful.

No. 18. Sandstone 1½ miles south-south-east of Ledbury Church.

No. 19. From quarry between Ross and Monmouth.

Nos. 20–1. Samples from the Saltwells inlier of Lower Downtonian rocks in the canal cutting south of Netherton Church, No. 20 being from the lowest sandstone exposed in the cutting, and No. 21 from the soft shales about 8 ft. below the basal Coal Measures.

In addition to references already given, papers by King and others (16, 17, 18, 19) should be consulted for stratigraphical details.

Distribution of Heavy Minerals.

The distribution of minerals in the Devonian is quite interesting. Sphene and pyroxene are absent, although the latter was suspected in one or two samples, while staurolite was definitely seen in only one rock.

Considering first Nos. 1–19, it is noticeable that garnet is consistently and extremely abundant throughout the Lower Devonian samples, and is abundant in some beds of the Upper division. Zircon varies in amount, anatase is very scarce in the Downtonian and Dittonian, while rutile is a very frequent mineral in all the rocks. Zircon, tourmaline, rutile, ilmenite, apatite, and anatase all appear to be more abundant in the Upper Old Red Sandstone.

Magnetite is very abundant, and barytes frequent in certain beds. The Lower Devonian rocks are more or less calcareous, but none of the Upper division samples contained calcite, while occasional grains of glauconite and chlorite appear in most of the residues. Muscovite is abundant in the Lower Devonian, and one or two grains of epidote were seen in sample No. 7.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
Downtonian.												
1.	8	4	6	10	–	1	4	9	2	5	–	–
2.	8	3	5	10	–	–	4	9	2	–	–	–
3.	5	2	2	10	–	–	2	8	5	8	–	–
4.	2	3	5	10	–	1	1	7	2	–	–	–
5.	8	1	5	8	–	–	1	9	4	–	–	–
6.	7	3	2	10	–	–	4	9	5	5	–	–
7.	6	2	5	9	–	–	1	8	5	–	–	–
8.	5	4	5	10	–	1	4	7	5	–	–	–
Dittonian												
9.	8	5	7	8	–	–	6	9	7	5	–	–
10.	8	4	6	10	–	1	2	9	5	7	–	–
11.	9	4	5	8	–	–	5	10	4	10	–	–
12.	9	4	5	9	–	1	1	8	8	–	–	–
13.	8	4	6	8	–	–	–	9	7	–	–	–
Upper Division.												
14.	8	5	7	8	–	1	9	8	7	–	–	–
15.	7	7	7	2	–	5	7	5	8	–	–	–
16.	8	7	5	1	–	5	8	5	9	–	–	–
17.	8	4	6	8	–	4	4	7	8	–	–	–
Beds of doubtful horizon.												
18.	5	4	7	9	1	1	5	9	4	–	–	–
19.	7	4	6	9	–	1	5	9	4	1	–	–
Saltwells Downtonian.												
20.	10	7	5	5	–	5	2	5	5	–	–	–
21.	5	7	4	8	–	4	5	5	5	–	–	–

The Saltwells beds of Lower Downtonian age are quite anomalous regarding their heavy minerals, and further investigation is needed to explain their variation from the type material.

Notes on the Minerals.

Zircon. Rather small grains. Occasionally rose-pink or lemon-yellow.

Rutile. Rarely yellow or geniculately twinned.

Garnet. Frequently brownish-red in colour, and dusky with abundant inclusions. Grains mainly perfectly rounded in form, and large in size.

Anatase. Small and very worn detrital grains.

Apatite. Occasionally of smoky tint.

In the Saltwells beds the anatase appears less worn, the apatite is occasionally smoky or banded, while magnetite occurs frequently as small spherical grains.

THE CARBONIFEROUS ROCKS.

The following is a list of the Carboniferous beds examined, arranged in approximately ascending sequence.

Basal Coal-measure Beds at Saltwells.

No. 1. Basal conglomerate and sandstone overlying the Downtonian sandstone at the canal cutting south of Netherton Church.

No. 2. Pebbly sandstone immediately above No. 1.

No. 3. Sandstone 10 ft. above No. 1.

These beds are described in Messrs. King and Lewis' paper (10).

Gornal Sandstone.

No. 4. Pale sandstone from Windmill Quarry, Upper Gornal. Specimens and slides of this material were kindly furnished by Mr. F. Raw. In a recent "Summary of Progress" (20) this sandstone is referred to the lower part of the Middle Coal Measures.

"Espley" Rock above Brooch Coal at Saltwells.

No. 4*a*. Sample from No. 2. Clay-hole, Saltwells. This grit of "Espley" type is presumably the one referred to in the "Summary of Progress for 1919" (14).

Old Hill Marl and Halesowen Sandstone Groups.

Nos. 5–6. Sandstones from the Old Hill Marls at Old Hill quarry.

No. 7. Conglomeratic "Espley" rock from same quarry.

No. 8. "Espley" rock of similar type from marl-pit between New Hawne and Witley Collieries.

No. 8*a*. "Espley" rock from Old Hill Marls of Lion Brick-pit, Mucklow Hill.

Nos. 9–10. Halesowen Sandstone from beds at entrance to Witley Colliery.

No. 10*a*. Halesowen Sandstone near top of Mucklow Hill.

No. 10*b*. Halesowen Sandstone from cliffs in Illey Road, Halesowen.

No. 10*c*. Sandy carbonaceous beds in stream bank near Illey Mill, probably belonging to the Illey sub-group of the Halesowen Sandstone (Kay, 23).

Detailed information concerning these beds may be found in papers by Kay (22), (24), and in the "Summary of Progress" for 1920 (3).

No. 10*d*. Sandstone from old quarry ½ mile north of Stagbury Hill.

No. 10*e*. Sandstone, ½ mile west of Bewdley.

No. 10*f*. Sandstone, 2 miles west of Bewdley on Cleobury road.

No. 10*g*. Sandstone below Keele cornstone, Stagbury quarry. Supplied by Mr. W. King.

These latter rocks, Nos. 10*d*-10*g* from the "Upper Coal Measures" of Wyre Forest, are described in a paper by Cantrill (43), and compared by him with the Halesowen Sandstone.

Keele Beds.

No. 11. Sandstone underlying "pellet-bed" in quarry south of Polesworth Waterworks.

No. 12. "Pellet-bed" of same quarry.

No. 13. Sandstone immediately above same "pellet-bed".

These samples were kindly supplied by Miss Tomlinson.

No. 14. Sandstone from the "Footprint-bed", Butt's Quarry, Alveley. Sample supplied by Mr. F. Raw.

Nos. 15–16. Sandstones from exposures about 1 and 1½ miles respectively south-south-east of Alveley.

No. 17. Sandstone, ¼ mile east of Hampton Loade Station.

No. 18. Keele cornstone from beneath breccia, Stagbury. (Supplied by Mr. W. King.)

No. 18*a*.[1] Sandstone, about ½ mile south-south-west of Hunnington Station.

No. 18*b*. Sandstone from excavation ½ mile north-west of Merritts Hill, Northfield.

No. 18*c*. Sandstone, Gannow Green, north-west of Rubery.

No. 19. Sandstone, about ½ mile from Bridgnorth on Wenlock road.

No. 20. Sandstone from above No. 19.

No. 21. Sandstone, a little west of Nos. 19 and 20.

Nos. 22–3. Sandstones from California Brick-pit, near Birmingham. Nos. 18*a*–23 are presumably of Keele age, but their exact stratigraphical position is doubtful.

In connexion with the nomenclature of the above-mentioned Carboniferous beds, Kay's paper (24) should be consulted. The Millstone Grit, a doubtful representative of which is but sparingly exposed in the district traversed, has been omitted, while the Enville Beds, overlying the Keele group, though provisionally regarded by H.M. Geological Survey as Upper Carboniferous (21), are included for convenience in the next section.

The distribution of the heavy minerals is given in the following table :—

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
Basal Beds of Coal Measures at Saltwells.												
1.	7	4	4	7	–	1	4	4	2	–	–	–
2.	8	2	4	8	–	2	5	9	8	–	–	–
3.	8	4	5	7	–	2	4	4	5	–	–	–
Gornal Sandstone.												
4.	9	7	5	1	–	7	8	7	8	–	–	–
"*Espley*" *grit above Brooch Coal.*												
4*a*.	–	–	–	4	–	–	4	–	2	–	–	–
Old Hill Marls.												
5.	5	4	2	2	–	–	7	9	8	1	–	–
6.	7	2	–	4	–	2	5	7	8	1	–	–

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[1] It should be borne in mind that it is at present difficult to assign certain sandstone bands in the Romsley–Frankley district definitely to either Keele or Enville group, and consequently there may be some slight overlapping in this paper. Professor Boulton's recent detailed mapping should help considerably in this connexion. The writer has included in the Keele Beds the deep red sandstones 18*a*, 18*b*, and 18*c*, and postponed consideration of certain other rocks of this area till the Enville Beds are dealt with (see footnote, p. 111).

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
“*Espley*” *rocks.*												
7.	4	2	1	1	–	–	4	9	9	9	–	–
8.	4	–	–	–	–	–	2	8	9	9	–	–
8*a*.	5	4	1	8	–	2	–	5	7	2	–	–
Halesowen Sandstone.												
9.	8	4	6	9	–	4	5	5	7	–	–	–
10.	8	5	7	9	1	7	7	5	8	–	–	–
10*a*.	8	5	8	10	3	6	6	7	8	9	–	–
10*b*.	6	4	4	6	–	4	7	4	7	–	–	–
10*c*.	9	7	8	5	–	7	–	7	8	8	–	–
“*Upper Coal Measures*” *of Wyre Forest.*												
10*d*.	7	4	4	8	–	1	–	4	8	–	–	–
10*e*.	8	4	7	8	–	6	–	7	7	–	–	–
10*f*.	7	2	4	9	–	2	–	9	8	–	–	7
10*g*.	7	4	6	4	1	2	2	7	7	–	–	–
Keele Group.												
11.	8	5	8	5	3	3	3	8	7	–	–	–
12.	8	5	7	8	5	1	4	9	7	5	–	–
13.	9	4	7	8	5	2	7	8	8	–	–	–
14.	9	7	8	7	–	5	7	9	7	–	–	–
15.	8	3	7	2	1	1	2	9	5	–	–	–
16.	9	5	8	–	–	6	5	9	7	–	–	–
17.	5	–	4	7	–	–	–	10	3	–	–	–
18.	7	1	5	5	–	1	–	8	5	-	–	–
18*a*.	8	4	7	4	1	3	4	9	6	–	–	–
18*b*.	9	4	7	7	1	3	3	9	7	–	–	–
18*c*.	8	4	6	7	1	3	4	9	7	7	–	1
19.	7	4	5	1	–	3	7	8	6	–	–	–
20.	9	5	7	1	1	4	7	7	8	–	–	–
21.	8	4	7	8	1	2	1	9	7	–	–	7
22.	9	5	8	7	4	6	–	7	7	10	–	–
23.	8	5	7	7	4	6	5	7	8	–	–	–

The “Espley” residues are generally scanty, and some of the Keele beds, e.g. No. 17, contain few mineral species. As a whole, the Carboniferous rocks are not very micaceous, muscovite being frequent only in some of the upper beds. It will be observed that zircon, tourmaline, rutile, garnet, magnetite, and ilmenite are generally present in considerable amount, magnetite, however, being subordinate to ilmenite, except in the reddish Keele group where magnetite predominates. Rutile and garnet become more frequent in the higher beds. Apatite is markedly prevalent throughout, but staurolite was noticed only in the upper part of the series. Anatase is frequent only in the Halesowen Sandstone and overlying beds, and in the Gornal Sandstone. Frequent small and beautiful grains in the latter sandstone are probably brookite, and indeed the whole assemblage of minerals from the Gornal rock forms a most striking microscopic study. The Saltwells basal beds contain abundant pyrites showing excellent crystal forms, and it is of interest to note that this mineral has been definitely observed by the present writer in only one other sample of sand, viz. from the whitish conglomerate and sandstone lying upon the igneous sill intrusive in the Cambrian at Dosthill, near Tamworth, and which, in Mr. Raw's opinion, is more probably of Carboniferous than of

Keuper age. Barytes is of rather frequent occurrence in the Carboniferous sandy beds, being locally abundant, more particularly in the tough conglomeratic "Espley" rocks. Calcite occurs occasionally as a cement, especially in the Keele group, while sphene was not observed in any of the residues. The frequency of pyroxene in two rocks is noteworthy. The "Espley" residues usually contain a quantity of ferrous carbonate as cementing material.

Notes on the Minerals.

Of all the strata from Cambrian to Trias, with the possible exception of the Lower Keuper sandstone, the Carboniferous rocks provide the most interesting mineral assemblages.

Zircon. Occasionally pink. Yellow grains occur sparingly in the Keele Beds.

Tourmaline. Small spherical grains occur in the Old Hill Marls and Halesowen Sandstone groups, while large rounded grains are found in the Gornal Sandstone.

Rutile. The Gornal and Halesowen sandstones have a percentage of yellow grains, and amber-coloured knee-shaped twins are somewhat frequent in the latter sandstone. Yellow grains become more frequent in the Keele Beds.

Garnet. Varying in size and degree of attrition.

Anatase. Worn tabular grains are most frequent, though pyramidal forms, outgrowths, and aggregates occur. As a rule worn detrital grains predominate, but fresh forms occur in the Gornal, Halesowen, and California sandstones.

Apatite. Occasionally very large in size. In some beds the grains are of the usual oval or worn prismatic type and are colourless, but in the Gornal Sandstone, Old Hill Marls, and Halesowen Sandstone, excellent prismatic grains occur, and many grains are dark-banded, yellowish-brown, or smoky purplish in colour and pleochroic. Hexagonal cross-sections have been observed revealing a rounded dark central core, and are apparently indicative of secondary growth rather than inclusion-cores.

Magnetite. Small spherical forms occur in the basal beds at Saltwells and in the Old Hill Marls and "Espley" rocks.

Ilmenite. Frequently fresh and unaltered in the Halesowen sandstones.

Barytes. Occasional crystal forms were seen in the Old Hill Marls, and in two Keele samples.

The pyrites grains present in the Saltwells samples vary from small to large in size, show excellent crystal forms, and are coated with a thin purplish layer of limonite.

The Halesowen sandstones contain occasional, medium-sized, deep green isotropic grains of rolled appearance, possibly green garnet, or spinel, and chlorite is present in the same beds.

The brookite (?) of the Gornal Sandstone occurs as small perfectly tabular or broken striated, bright yellow grains. Pyroxene appears as medium-sized, lavender or smoky, irregular or worn prismatic grains.

THE ENVILLE AND "PERMIAN" ROCKS.

The exact stratigraphical position of the so-called "Permian" of the Midlands is still a matter of doubt, and is discussed by Mr. Whitehead in a recent "Summary of Progress" (21). Pending a satisfactory decision as to the exact relationships of the Midland rocks lying between the Keele series of the Carboniferous and the Lower Mottled Sandstone of the Trias, it would appear convenient to group the rocks under the following headings, and then to note important resemblances or differences between their heavy residues:—

A. The calcareous conglomerates and sandstones of Bowhills, Enville, and Warshill, the "Middle Permian" of King (26).
B. The breccias and sandstones of Enville, Gatacre, and Castle Hill, the "Upper Permian" of King (27).
C. The "Middle Permian" conglomerates, etc., of Gospel End and Baggeridge (28).
D. The Hamstead Quarry Series of Great Barr (25, 32, 33).
E. The Corley Beds of East Warwickshire (8).
F. The Hopwas Breccia (33, 34, 35, 36).
G. The Breccias of Sutton Park (34).
H. The Nechells Breccia (33).
I. The sandstones beneath the Bunter Pebble beds of Barr Beacon (34).
J. The Polesworth and Leicestershire Breccias (37).
K. The Northfield Breccia (29).
L. The Warley Breccia (30).
M. The Clent Breccia (31).
N. The Breccias of Haffield, Alfrick, Knightwick, Berrow, Abberley, and Church Hill (38).
O. The Alberbury Breccia (39).

A.[1] "*Middle Permian*" *of Bowhills, Enville, and Warshill.*

Samples from the following localities were examined. Of these No. 8 was supplied by Mr. W. King and the letters refer to the nomenclature adopted by him (26).

No. 1. Sandstone, approximately ½ mile south-south-west of Coton Hall (A 2).

No. 2. Conglomerate, approximately ½ mile south by west of Coton Hall (B 1).

No. 3. Sandstone from the lower part of quarry near Tuckhill (B 1).

No. 3*a*. Sandstone several feet above No. 3 (B 1).

No. 4. Conglomerate from top of Tuckhill quarry (B 1).

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[1] Calcareous conglomerate of "Mid-Permian" type from a well-sinking at Merritts Hill, Northfield, and two sandstones, one very calcareous, from an exposure ½ mile to the north were examined, and the residues found to agree closely with those of the beds examined in Section A.

No. 5. Sandstone from Broad Oak Hill (B 1).
No. 6. Sandstone 10 ft. above No. 5 (B 1).
No. 7. Sandstone from Four Ashes (C 1).
No. 8. Cornstone below breccia at Warshill (B 1).

The heavy minerals are distributed as follows:—

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	9	4	7	4	–	2	2	9	7	–	–	–
2.	8	4	6	4	–	–	2	9	5	–	–	–
3.	8	4	7	3	–	1	1	9	5	1	–	–
3*a*.	8	4	7	4	1	1	2	9	7	–	–	–
4.	9	4	7	4	–	2	3	9	7	–	–	–
5.	8	4	7	4	1	1	3	9	5	–	–	–
6.	8	4	7	2	–	2	2	9	7	–	–	–
7.	8	4	7	4	1	2	–	9	7	–	–	–
8.	8	4	7	4	–	–	–	8	7	–	–	–

The subordination of tourmaline, garnet, staurolite, and anatase is a noteworthy feature, especially when comparing these "Middle Permian" rocks with the overlying breccias. The consistency of the results is also remarkable when it is remembered that various beds and facies are compared, and there is a big difference between the "Middle Permian" suites and those of the so-called "Lower Permian" or Keele beds.

Notes on the Minerals.

Zircon. Occasionally rose-pink or yellow.

Rutile. Yellow and crimson grains occur.

Garnet. Small and frequently dusky, rounded grains.

Staurolite. Not large, but pale and worn.

Anatase. Detrital.

Apatite. Small.

Most of the samples were very calcareous.

B. "*Upper Permian*" *Breccias, etc., of Enville, Gatacre, and Castle Hill.*

These are from Mr. W. King's D 1 division, and samples Nos. 4, 4*a*, and 5 were supplied by him.

No. 1. Bedded sandstone and fine breccia, about 200 yards south-east of Gilbert's Cross.

No. 2. Gritty sandstones, about 100 yards south-east of Gilbert's Cross.

No. 3. Breccia a little north of Six Ashes.

Nos. 4 and 4*a*. Breccia-sandstone, approximately 400 yards east-north-east of Gatacre Park Farm.

No. 5. Breccia-sandstone from Castle Hill, south of Enville.

Distribution of Heavy Minerals.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	8	4	7	6	2	2	4	9	5	1	–	1
2.	7	2	4	4	–	2	2	9	4	–	–	–
3.	7	4	5	5	1	1	1	8	6	–	–	–
4.	8	2	7	8	1	2	3	9	5	–	–	–
4*a*.	8	2	5	7	3	2	3	9	4	–	–	–
5.	8	2	7	7	2	1	5	9	4	–	–	–

Increase in amount of garnet, apatite, and staurolite, and decrease in tourmaline, differentiate these "Upper Permian" breccias from the "Middle Permian" of the same district.

Notes on the Minerals.

Zircon. Occasionally rose-pink or yellowish. Grains somewhat less worn than in foregoing section, and this remark applies to the other minerals.

Rutile. Geniculate twins of amber, foxy, or yellow colour occur.

Garnet. Medium sized, rounded, and sub-angular.

Apatite. Some fairly well shaped, one remarkably long slender prism being observed.

Chlorite. Occurs occasionally.

One breccia was very calcareous, and a grain of lilac-coloured pyroxene was seen in sample No. 1.

C. *The "Middle Permian" of Gospel End and Baggeridge.*

The following are mainly from the C 1 division of Mr. King.

No. 1. Conglomerate from roadside section at Gospel End.

No. 2. Sandstone band in same section.

No. 3. Sandstone from Common between Gospel End and Baggeridge Wood.

No. 4. Thick conglomerate from old quarry in Baggeridge Wood.

No. 5. Sandstone with pebbles lying above No. 4.

Distribution of the Heavy Minerals.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	8	4	7	7	1	2	1	9	7	–	–	–
2.	8	4	7	5	–	4	4	9	7	–	–	1
3.	9	5	7	3	–	4	2	9	8	–	–	–
4.	8	4	7	3	–	2	2	9	7	–	–	–
5.	8	4	6	4	–	1	1	9	7	–	–	–

The "Middle Permian" beds of Baggeridge agree closely with those of Bowhills and Enville as regards both character and distribution of heavy minerals, except in the unusual frequency of garnet in samples Nos. 1–2. A grain of pyroxene was seen in No. 2.

Notes on the Minerals.

Anatase. Some grains less worn than usual, but no sharp-edged fresh forms such as occur, for instance, in the Lower Keuper.

Apatite. One dark-cored grain.

D. *The Beds at Hamstead, near Great Barr.*

Nos. 1–4. From the "New Quarry", Hamstead. These samples, the lowest rocks examined at Hamstead, were from the "New Quarry Marl sub-group" of Hardaker.

Nos. 1 and 2 were taken about 30 ft. below the conglomerate next described.

No. 5. From the "Rock Farm Conglomerate" of Hardaker, New Quarry, Hamstead.

No. 6. From the Old Quarry, Hamstead.

No. 7. From roadside near Hamstead village. Samples 6 and 7 are referable to the " Old Quarry Sandstone subgroup " of Hardaker, lying above the New Quarry Marls, and separated from them by the Rock Farm Conglomerate.

Nos. 8–9. From Canal Cutting, Hamstead.

Nos. 10, 11, and 12. From Rocky Lane, Hamstead.

No. 13. From Canal Cutting, Hamstead.

Nos. 8–13 are from the " Manor House Breccia and Sandstone subgroup " of Hardaker.

The distribution of the chief heavy minerals is given below :—

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
The beds at Hamstead.												
1.	8	4	7	1	–	1	4	9	5	–	–	–
2.	8	4	7	1	–	1	4	9	5	–	–	–
3.	8	3	6	3	2	2	4	9	5	–	–	–
4.	8	5	7	3	2	4	4	8	7	–	–	–
5.	8	5	6	2	2	1	1	9	7	1	–	–
6.	8	5	6	3	1	2	3	9	7	–	–	–
7.	8	4	7	2	1	2	1	9	7	–	–	–
8.	8	4	7	4	2	3	1	9	7	–	–	–
9.	8	4	5	4	–	1	2	9	5	–	–	–
10.	8	3	6	4	1	1	1	9	5	1	–	–
11.	9	4	7	4	1	4	2	9	5	–	–	–
12.	8	3	5	5	1	1	1	9	5	–	–	–
13.	8	5	7	5	1	2	3	9	7	–	–	–

These " Hamstead beds " resemble generally the above-described " Middle Permian " in their heavy mineral suites. Staurolite tends to be more frequent, but the poor variety and general appearance of the residues remind one strongly of the " Middle Permian ". Calcite is abundant in the lower beds, Nos. 1–5.

Notes on the Minerals.

Rutile. Yellow grains occur.

Staurolite. Rather worn in appearance.

Anatase. Detrital ; fair-sized somewhat worn grains occur.

Apatite. Occasionally large. Rarely banded or well formed. Chlorite appears in most slides, while brookite and a greenish, isotropic mineral, which may be green spinel or garnet, occur.

E. *The Corley Beds of East Warwickshire.*

Mr. Eastwood, in the Coventry Memoir (8), gives a table indicating approximately the chief subdivisions of the above beds, and samples were collected covering practically the whole vertical range, with the exception of the Tile Hill marls and sandstones.

No. 1. Conglomerate from Arley Station.

No. 2. Sandstones from 1 mile north-west of Arley Station.

Nos. 3–5. Sandstones from Corley Rock section, in ascending order from base to top.

Nos. 6–9. Sandstones from Meriden Hill.

Nos. 10–12. Sandstones from Allesley.

Distribution of Heavy Minerals.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	8	3	5	8	1	–	–	9	4	–	–	–
2.	8	4	6	7	–	1	1	9	5	–	–	–
3.	8	5	7	4	–	2	4	9	7	–	–	–
4.	8	4	7	2	1	–	–	9	5	–	–	–
5.	8	4	7	3	1	1	–	9	5	–	–	–
6.	8	4	7	8	2	4	4	9	7	–	–	–
7.	8	5	7	8	–	2	–	9	9	–	–	–
8.	9	4	7	8	1	1	5	9	7	–	–	–
9.	8	4	7	8	–	–	1	9	8	–	–	–
10.	8	4	7	7	1	1	–	9	7	–	–	–
11.	8	4	7	7	1	1	–	9	5	–	–	–
12.	8	4	7	7	–	–	–	9	5	–	–	–

The resemblance of the above samples, especially as regards tourmaline, staurolite, and anatase, to those in sections A, C, and D is noticeable, but garnet is as frequent as in B, with the exception of the Corley Rock samples. Sample No. 1 was markedly calcareous, and calcite was found in certain beds at Meriden.

Notes on the Minerals.

Zircon. Purple grains rather frequent.
Rutile. Knee-shaped twins rare.
Garnet. Medium-sized, rounded, or sub-angular.
Anatase. Detrital.

F. *The Hopwas Breccia.*

Materials from Hopwas gravel-pit contained the following minerals :—

Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
8	5	7	5	4	1	2	9	7	2	–	–

The frequency of garnet, staurolite, and tourmaline is of interest. Calcite is very abundant.

Notes on the Minerals.

Zircon. Pink and yellow grains occur.
Garnet. Medium-sized, sub-angular or rounded forms.
Staurolite. Rarely large in size.
Anatase. Detrital in character.
Magnetite. Occasionally shows squarish forms.
Barytes. Large irregular flakes of speckled or dirty appearance.

G. *The Breccias of Sutton Park.*

In the Lichfield Memoir (34) these breccias are treated as identical in horizon with the Hopwas material. The following is a list of the samples examined.

Nos. 1–4. Breccia below Bunter Conglomerate at Keeper's Pool Quarry. Samples in ascending order over a thickness of 9 feet.

No. 5. Breccia immediately beneath Bunter Conglomerate at Black Root Pool Quarry.

No. 6. Large fragment of hard calcareous breccia from same place. Not found in situ, but presumably from beneath the conglomerate in this quarry.

Distribution of Heavy Minerals.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1	7	5	5	7	4	–	4	9	7	7	–	–
2.	8	5	5	5	4	1	4	9	5	7	–	–
3.	8	5	7	5	1	–	4	9	5	1	–	–
4.	8	5	7	6	3	4	–	9	7	1	–	–
5.	8	4	7	4	2	2	–	9	5	–	–	–
6.	8	5	7	4	2	2	–	9	7	5	–	–

Comparing these breccias with the typical Hopwas material it is noteworthy that they agree regarding the frequency of tourmaline, garnet, and staurolite, while apatite appears more frequently. Too much importance must not be attached to samples 5 and 6, 5 being taken very close to the overlying Pebble Beds, and 6 being of somewhat different type to the other samples. Not being seen in situ, some doubt arises regarding its exact horizon, though it seems almost certainly to be a part of the breccia formerly well seen at Black Root Pool Quarry.

Notes on the Minerals.

Only No. 6 is calcareous.

Garnet, Staurolite, and Anatase. As in F.

Apatite. Occasionally brownish-blue.

Barytes. In Nos. 1 and 2 more or less perfect crystal forms occur very frequently and may be due to the re-crystallization of previously existing cementing material. It does not occur in the Bunter Conglomerate immediately overlying the breccia. Samples 3 and 4 lying above Nos. 1 and 2 contain only occasional grains of similar character, while 6 contains barytes of ordinary type.

H. *The Nechells Breccia.*

Two samples from the cores of the Nechells boring were examined. The exact horizons of the samples are somewhat doubtful, but both are probably from about 70 feet above the base of the breccia, i.e. from a depth of 606 feet (33, p. 346). The following minerals were observed:—

Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
8	5	6	4	2	1	4	10	7	7	–	–

In general the residues resemble those of the Hopwas Breccia, but magnetite is predominant, and frequently shows squarish forms. The rock is very calcareous. Barytes is very frequent as large, dirty, irregular flakes and splinters. The other minerals have similar characteristics to those of Hopwas and Sutton.

I.[1] *The Sandstone beneath the Bunter Pebble Beds at Barr Beacon.*

The large pit near the cross roads west of Barr Beacon, showing about 40 feet of sand and fine brecciated material beneath the Pebble Beds, was examined, and five samples collected in ascending order from the whole thickness exposed.

The heavy minerals are as follows :—

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	8	5	7	–	3	2	–	9	5	–	–	–
2.	8	5	7	–	4	4	–	9	7	–	–	–
3.	8	5	7	–	4	–	–	9	7	–	–	–
4.	9	5	7	–	2	1	–	9	5	–	–	–
5.	9	5	7	–	2	2	–	9	7	–	–	–

In this sandstone, the increase in tourmaline, shown by F, G, and H, is maintained, staurolite and detrital anatase occur in small amounts, but garnet and apatite are completely absent. As regards garnet this is a striking fact, differentiating the residues from any others in this section. The only beds that provide similar residues are those of the Lower Mottled Sandstone of the Bunter, where garnet and apatite are scarce and sometimes absent.

Notes on the Minerals.

The minerals characteristics, however, are not altogether those of the Lower Mottled Sandstone.

Zircon. Occasional yellowish-green oval grains occur, and some purplish ones.

Rutile. Various colours, but mainly amber. Geniculate twins occur.

Staurolite. Of medium size.

Anatase. Detrital.

Magnetite. Occasionally square in outline.

Calcite. Absent.

Although one would hesitate to assert with Landon (40) that these beds belong to the Lower Bunter, yet the mineral residues of the above sandstone certainly seem to resemble those of the Lower Mottled Sandstone, rather than those of the Hopwas and Sutton Breccias, or indeed any other "Permian" beds.

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[1] Since the above was written Professor Boulton's description of the Nechells Breccia has appeared (33), from which it is seen (pp. 363, 373) that he regards the sandstone at Barr Beacon as the basal bed of the Pebble Beds. This is not confirmed by a consideration of the heavy minerals, nor does the general appearance and lithology of the beds compare with those of basal Bunter beds as seen elsewhere at Ribbesford and Habberley. Perhaps such a resemblance would not be expected in the present instance, but one would expect the mineral residue of the Barr sandstone to resemble more closely that of the Bunter conglomerate beds above. In the writer's opinion, the only rocks of similar type in the locality are certain sands containing fine brecciated material occurring in the canal beds at Hamstead about 2½ miles to the south of Barr Beacon on the same line of outcrop, and lying beneath the Pebble Beds in much the same way as those at Barr, but here again we are not freed from the difficulty of explaining the absence of garnet which is prevalent in the canal beds at Hamstead, as well as in the Bunter Pebble Beds and the Hopwas Breccia. In the discussion on Professor Boulton's paper (p. 372), Mr. Dixon remarked that the Barr sandstone may represent a lateral passage between the Hopwas Breccia and Lower Mottled Sandstone, and his suggestion that it may approach the one as it departs from the other in the character of its heavy minerals is worthy of note.

J. *The Polesworth and Leicestershire Breccias.*

Samples from the former from an exposure on the Polesworth–Warton road, about ½ mile east of Polesworth, were kindly furnished by Mr. and Miss Tomlinson. Several specimens, taken in ascending order, were examined. Pieces of the Leicestershire breccias from Oakthorpe, near Ashby, were also investigated.

Distribution of Heavy Minerals.

	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
Polesworth	8	4	6	5	1	1	4	9	6	1	–	–
Oakthorpe	8	4	7	5	3	2	5	9	6	9	–	–

The residues do not differ greatly from those of F, G, and H.

Notes on the Minerals.

Zircon. Pale, yellow, oval grains frequent.

Anatase. Detrital.

Magnetite. Squarish forms occur.

All the samples were very calcareous.

K. *The Northfield Breccia.*

This rock, lying somewhat apart from the Clent breccia, about 1 mile north-west of Northfield Station, is treated separately.

Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
8	3	7	6	2	1	5	9	7	1	?	–

As might perhaps be expected, the residue resembles those of the "Upper Permian" of Enville and Clent. The breccia is very calcareous. Chlorite, apparently resulting from alteration of biotite, occurs.

L. *The Warley Breccia.*

Sample No. 1 was taken from the roadside exposure between Warley and Bristnall Fields, and No. 2 is a specimen of breccia-sandstone supplied by Mr. W. King from the Londonderry boring near Langley.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	8	4	6	4	3	1	–	9	5	–	–	–
2.	9	4	6	1	1	1	2	8	5	–	–	–

The comparative scarcity of garnet in No. 2 is noteworthy. No. 2 was calcareous.

M. *The Clent Breccia.*

Samples were collected as follows:—

No. 1. Clent Breccia from exposure ¾ mile south-west of St. Kenelm's Church.

No. 2. Similar material from Beacon Hill, between Lickey and Rubery.

No. 3. Breccia from Rose Hill Estate, Lickey.

No. 4. Breccia from lane on west side of Great Farley Wood.

No. 5. Part of breccia-sandstone core containing indefinite plant remains, supplied by Mr. W. King from the Stourbridge Goods Station Borehole, about 40 feet below the Lower Mottled Sandstone of the Bunter.

Distribution of Minerals.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	8	4	5	7	1	1	1	8	8	–	–	–
2.	9	4	7	7	3	2	5	9	8	–	1	–
3.	9	4	7	7	2	2	4	9	7	–	–	–
4.	7	4	5	7	1	2	4	9	4	–	–	–
5.	8	4	5	4	3	–	5	9	4	7	–	–

The resemblance between the residues from the Clent and Enville districts has already been remarked upon. The rocks are not calcareous.

Notes on the Minerals.

Zircon. Rather less worn than usual. Occasionally pink.

Rutile. Appears in a wide range of colours.

Garnet. Frequently large, more or less rounded, and rarely coloured.

Anatase. Detrital tabular, less frequently pyramidal forms.

Magnetite. Occasionally showing squarish outlines.

Sphene. Several brownish grains in one sample, one worn elongated diamond form being present.

Barytes. Small, irregular, with a tendency to crystalline shape.

Chlorite. Probably from biotite. Possibly green garnet or spinel occur occasionally.

N. *The Breccias of Haffield, Abberley, etc.*

Breccias from 1 (Haffield), 2 (Alfrick), 3 (Knightwick), 4 (Berrow Hill), 5 (Abberley), and 6 (Church Hill, near Bayton) were examined. Samples 2, 3, 4, and 5 were supplied through the courtesy of Mr. W. King.

Distribution of the Heavy Minerals.

Locality.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
1.	9	4	7	7	1	–	5	9	5	2	–	–
2.	8	4	7	7	4	–	4	9	5	–	–	–
3.	8	4	5	6	–	2	5	9	5	–	–	–
4.	7	4	6	5	1	1	4	9	7	–	–	–
5.	5	4	4	6	–	–	1	8	7	–	–	–
6.	7	4	5	9	1	1	4	9	4	–	–	–

Generally, the residues from the above breccias resemble those from the Clent and Enville "Upper Permian" rocks, especially in the subordination of tourmaline and the frequency of garnet, and, with exceptions, of staurolite.

Notes on the Minerals.

Zircon. Occasionally rose-pink or yellow.

Rutile. Knee-shaped twins uncommon

Staurolite. Medium to large in size.

Anatase. Detrital, or occasionally as aggregates.

Apatite. One or two banded grains and good prisms occur.

Magnetite. Occasionally showing squarish contours, the Alfrick rock containing abundant such grains with sharp outlines.

Barytes. In Haffield Breccia, occurs as angular crystalline forms.

Sphene. May be present in the Osebury Rock of Knightwick.

Green Garnet. May occur, and chlorite appears as large yellow flakes in the Abberley Breccia.

Calcite. The Haffield and Alfrick rocks are calcareous, and the Osebury Rock contains a little calcite.

O. *The Alberbury Breccia, Shrewsbury.*

Several samples of this calcareous rock were examined.

Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.	Ba.	Sph.	Pyr.
8	4	6	3	–	2	5	9	5	–	–	–

Garnet is infrequent, and staurolite was not seen. The appearance of the heavy residue does not call for special remark.

It is not easy to summarize the data resulting from the examination of the rocks in this section, but if the various beds be grouped according to general similarity of stratigraphical occurrence, and according to present-day views as to their relative age, it will be seen that such groups present certain fairly well-defined differences. Omitting reference to the minerals zircon, rutile, anatase, magnetite, ilmenite, sphene, and pyroxene, which are either infrequent or else show little variation in abundance or appearance, the following characteristics become apparent :—

Group I includes the "Middle Permian" of the Enville and Baggeridge districts, the Hamstead and Corley rocks, and perhaps the Alberbury breccia, sections A, C, D, E, and O. In these rocks garnet is fairly frequent, staurolite very scarce, and apatite scarce. The exceptions are the frequency of garnet in some of the Corley beds (E), and the slight increase in staurolite in the Hamstead beds (D). Barytes occurs occasionally in small amount. The heavy minerals are few in number, and show little variation in appearance. Some of the rocks are very calcareous.

Group II comprises the "Upper Permian" of Gatacre, Clent, and Northfield, and the breccias of Haffield, Alfrick, Knightwick, Berrow, Abberley, and Church Hill sections, B, K, M, and N. In this group garnet is very frequent, staurolite variable, but usually fairly frequent, while apatite is also fairly frequent. Barytes occurs as in Group I. The residues are much more interesting than those of the first group, both as regards number of mineral species and in variety of appearance. With a few exceptions, the breccias are not calcareous. The Warley breccias require further investigation before deciding to which group they should be attached.

Group III. In this group are placed the various breccias underlying the Trias east of the South Staffordshire coalfield, sections F, G, H, and J. Tourmaline is more frequent than in either of the first two groups, garnet frequent, and staurolite and apatite fairly frequent. Barytes is much more commonly met with. Generally speaking, the breccias are very calcareous and contain residues with a fair selection of minerals of varied appearance.

Group IV. The beds at Barr Beacon (I) must be placed in a separate category in consequence of the absence of garnet and apatite. Tourmaline is as frequent as in Group III, but barytes and calcite are absent.

THE TRIASSIC ROCKS.

As already stated, an account of the Midland Triassic Sandstones and the chief heavy minerals contained in them, was given in the writer's earlier paper (1), but the following notes embody the results of more extended investigations upon Triassic material up to, but not including, the Keuper Marl. In all, 128 samples have been examined, comprising :—

Keuper.	Lower Keuper Sandstone .	50
Bunter.	Upper Mottled Sandstone .	22
	Conglomerate Beds . . .	39
	Lower Mottled Sandstone .	17
	Total . . .	128

The Lower Mottled Sandstone was examined in the Stourbridge–Kidderminster–Bridgnorth area. The Bunter Conglomerate beds in the same area were dealt with, together with samples kindly furnished by Mr. W. Wickham King from the Ashwood Borehole, while east and south of the South Staffordshire coalfield the Conglomerate beds of Sutton, Lichfield, and the Lickey were investigated. The Upper Mottled Sandstone was examined in the Stourbridge-Bromsgrove district, other samples being obtained from Bromesberrow, near Malvern, Astley, near Stourport, Lichfield, and Erdington. Lower Keuper Sandstone was sampled in the Northfield-Bromsgrove, Clent-Stourport, Ombersley, Sutton, Lichfield and Ashby areas. The relative frequency of the most common minerals is given in the following paragraphs :—

Bed.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.
Lower Mottled Sandstone	7	5	4	2	4	–	–	8	6
	Anatase was found in five samples, being scarce or very scarce in each. Apatite was found in four samples, ranging from very scarce to fairly frequent. Garnet was absent from two samples.								
Bunter Conglomerate Beds.	8	6	6	5	5	2	4	9	7
	Garnet is variable in amount, being locally scarcer in the Lickey district. Staurolite varies from very scarce to very frequent in different localities, while anatase and apatite were absent from several samples.								

Bed.	Z.	T.	R.	G.	St.	An.	Ap.	M.	Il.
Upper Mottled Sandstone.	9	6	7	5	4	3	5	9	6
	Garnet is locally abundant near Lichfield, and apatite varies in occurrence from fairly frequent to very abundant.								
Lower Keuper Sandstone.	8	5	6	8	3	5	5	9	7
	Staurolite was absent from four samples, but anatase and apatite were found in every sample, though in varying amounts.								

The less frequent minerals occur as follows, the numbers in parentheses indicating range in frequency :—

Bed.	Ba.	Sph.	Ca.	Pyr.
L.M.S. . .	In 2 samples. (4–10).	—	—	In 3 samples. (1–4).
B.C. . .	In 5 samples. (1–9).	—	In 4 samples.	In 6 samples. (5).
U.B. . .	—	—	—	—
L.K.S. . .	In 5 samples. (2). Locally abundant in one sample.	—	In 3 samples.	In 3 samples. (2–4).

The Lower and Upper Mottled Sandstones present residues somewhat restricted as regards variety of minerals. In the Lower Bunter the subordination of rutile, and the relative scarcity of garnet, anatase, and apatite are noteworthy. Tourmaline, rutile, and apatite become frequent or very frequent in the succeeding beds, and the increased amount of garnet and authigenous anatase in the Lower Keuper is a feature of diagnostic value.

Notes on the Minerals.

Lower Mottled Sandstone.

Zircon. Very worn or rounded grains, occasionally pink. Yellow, egg-shaped and cracked forms occur.

Tourmaline. Rarely prismatic. Grains sometimes full of large inclusions.

Rutile. Occasionally yellow or crimson. Rarely prismatic or twinned.

Garnet. Rounded forms, occasionally salmon-pink in colour.

Staurolite. Sometimes very large (·3 mm.). Pale to deep brownish-yellow and angular.

Anatase. Rarely present as individual detrital grains. Usually as aggregates of small or dark tabular crystals or outgrowths upon leucoxene.

Magnetite. Occasionally very large (·5 mm.); usually well-rounded and coated with resistant haematite.

Ilmenite. Leucoxenic, occasionally very large (·5 mm.).

Barytes. In one sample as very large, angular, and jagged forms.

Pyroxene. Small or medium, dull purplish or smoky grains, angular or sub-angular with indications of prismatic form.

Bunter Conglomerate Beds.

Zircon. Yellow and pink grains occur. Occasional yellow egg-shaped forms.

Rutile. Geniculate twins occur.

Garnet. Rolled and sub-angular grains.

Staurolite. Frequently very large, and richly coloured.

Anatase. Worn tabular detrital forms, rarely fresh. Occasionally pyramidal or as aggregates.

Apatite. Occasional long slender forms. Sometimes banded, rarely bluish.

Magnetite. Mostly coated with red oxide.

Ilmenite. Usually altered to leucoxene.

Pyroxene. Small or medium, smoky or pale lilac grains. Angular or sub-angular prismatic forms.

Grains of muscovite, green and brown mica (biotite) showing pleochroic haloes, and chlorite occur.

Upper Mottled Sandstone.

Zircon. Occasionally yellow or pink.

Rutile. Geniculate twins occur.

Garnet. Sub-angular or rounded grains.

Anatase. Fresh grains and aggregates rare.

Apatite. Frequently large. Worn prisms, occasionally long and slender. Banded grains occur.

Magnetite. Usually well-rounded; frequently coated with haematite.

Ilmenite. Usually leucoxenic.

Brownish-green mica, muscovite, and chlorite occur.

Lower Keuper Sandstone.

Zircon. Yellow egg-shaped, and purplish-pink grains frequent.

Tourmaline. Occasionally quite spherical.

Rutile. Sometimes yellow, dark-brown or crimson. Amber-coloured knee-shaped twins occur.

Garnet. Occasionally very large. Sub-angular and rounded grains, frequently salmon or deep pink in colour.

Anatase. Usually sharp-edged, fresh tabular forms. Frequently large and occasionally pyramidal. Yellow, steel-blue or dark in colour. Often occurring as outgrowths, probably on leucoxene, or as aggregates entirely replacing the latter mineral. A few detrital forms appear, but the grains are mainly authigenous.

Apatite. Usually as colourless grains, but smoky brownish-purple pleochroic prismatic forms occur, while others have broad dark cores or bands. These may be elongated, but rounded or oval grains predominate.

Magnetite. Occasionally slightly haematitic.

Ilmenite. Usually leucoxenic.

Barytes. Frequently very large, angular splinters, speckled or dingy in colour. Small crystalline forms occur in certain beds.

Pyroxene. Medium or large, dark smoky and broken or sub-angular grains. Other minerals include large rounded and scratched flakes of muscovite with strain-shadows, brown mica with pleochroic haloes, plagioclase, green garnet or spinel, chlorite and possibly topaz and hornblende.

SUMMARY.

The chief features exhibited by the heavy mineral residues from the various formations will now be summarized, but it is difficult to show, by tabulating or otherwise, the differences or resemblances between residues, although such may be quite obvious to the investigator. This is because the differences consist of a sum total of variations in size, shape, colour, and frequency of the minerals contained in the residues under examination, and it is scarcely possible to indicate such differences in writing, without frequent repetition of words, thereby involving a loss in clarity of expression, or if tables be employed, without losing sight of other connected data.

The Cambrian Rocks, which are mainly non-calcareous, very glauconitic, micaceous, and chloritic, yield residues with few mineral species. Ilmenite is abundant; apatite and garnet are variable in occurrence but rarely frequent. The coating of the titanium minerals with quartz in the shales, and the well-rounded zircon and abundance of fresh anatase forms in the quartzites are noteworthy.

The Ordovician residues were from a few, by no means typical, rocks, glauconitic, and micaceous, but non-calcareous. The heavy minerals are limited in species. Garnet is abundant.

The Silurian rocks examined are also not typical, consisting only of the non-calcareous slightly glauconitic and micaceous Llandovery sandstones. They are notable for their fresh anatase forms. Zircon is well-rolled, rutile only occasionally present, while garnet and apatite are scarce. Staurolite makes its first appearance in these beds.

The Devonian rocks may be considered under two headings: (*a*) Lower Devonian (Downtonian and Dittonian) and (*b*) Upper Devonian. The former are more or less calcareous, micaceous, and chloritic, and contain restricted residues with extremely abundant well-rolled, brownish-pink garnet, frequent apatite and rare anatase. Barytes is frequent in some beds. The Upper Devonian samples were non-calcareous, and not very micaceous. Garnet is abundant, and anatase considerably more frequent than in (*a*).

The Carboniferous beds examined are confined to the Coal Measures and may also be treated in two sections: (*a*) the greenish, grey, and pale sandstones from various horizons below the Keele Beds, and (*b*) the upper red measures or Keele Beds. The first are generally non-calcareous, and rarely micaceous. They are interesting as regards both number of mineral species and the variety of form and appearance of the grains. The occurrence of unaltered ilmenite, frequency and pleochroism of apatite, and the occasional spherical forms of magnetite and tourmaline are outstanding features. In the higher beds (Halesowen Sandstone) garnet and rutile are more abundant and staurolite appears. Barytes occurs rather frequently and pyroxene was seen for the first time in one sample. The pyrites in the basal conglomerate at Saltwells calls for remark. The upper or Keele Beds (*b*) usually contain abundant magnetite, and are sometimes calcareous, but the residues are less varied than those of the lower beds. Pyroxene was seen in one sample.

The rocks of *the Enville and " Permian "* beds are, as stated above, placed provisionally in four groups: (I) the " Middle Permian " conglomerates, Hamstead, and Corley beds in which garnet is generally infrequent and staurolite and apatite scarce; (II) the Breccias of Gatacre, Clent, Northfield, and isolated outcrops in the Severn basin, containing varied residues with frequent garnet, occasional staurolite and fairly frequent apatite; (III) the Hopwas and allied breccias with varied residues containing frequent tourmaline and garnet, fairly frequent staurolite and apatite, and frequent barytes; and (IV) the anomalous Barr beds in which garnet, apatite, barytes, and calcite are absent. In the " Permian " and Enville rocks sphene and pyroxene were occasionally noticed.

The Triassic rocks are generally non-calcareous, but usually micaceous. Pyroxene occurs more freely than in the older formations.

1. The Lower Mottled Sandstone is characterized by rather poor residues containing little rutile and garnet, scarce anatase and apatite, but fairly frequent large staurolite grains.
2. The Bunter Conglomerate beds contain frequent tourmaline, garnet, large ragged staurolite, apatite, and some detrital anatase.
3. The Upper Mottled Sandstone is marked by abundance of zircon, frequency of tourmaline, garnet, rutile, and apatite, but general lack of other minerals.
4. The Lower Keuper Sandstone provides varied assemblages of minerals in which garnet, frequently large and pink, is abundant, apatite frequent, and consistently occurring fine fresh anatase forms appear.

NOTES.

Felspar. This mineral is considerably more frequent in several formations than has been indicated, but its detailed investigation has been left till further work on the less frequent minerals has been carried out.

Monazite. A suggestion by Mr. Macdonald Davies regarding the possibility that certain yellowish grains resembling zircon might prove to be monazite, led the writer to examine some of these more closely, but no definite evidence was obtained as to the presence of monazite, and the point must remain in abeyance till further determinative methods have been applied, though it is more than probable that these grains are monazite.

Sphene. Although definitely observed only in one or two residues, it is probable that sphene occurs more frequently, and has been overlooked in consequence of its general resemblance to rutile and anatase when poorly developed and discoloured.

Anatase. At various horizons certain grains of a titanium mineral occur, which may be either anatase or brookite. They are usually of an orange-yellow or clear straw colour with good contours and but little worn, and frequently show marked striation or cleavage and brighter colours under polarized light than is the case with anatase and rutile.

Glauconite. For reasons stated above (p. 100) the relative frequency of occurrence of glauconite at various horizons has not been recorded in detail, but it appears to occur at many levels from Cambrian to Trias. As Mr. Dixon points out, it is difficult to account for its appearance in beds other than those of marine type, and he suggests that grains resembling discoloured glauconite may ultimately prove to be volcanic ash or chamosite. The writer agrees on this point (see note on chlorite below), but undoubted grains of green glauconite occur in many post-Silurian residues, and have presumably been derived from the underlying Cambrian rocks of the district.

Chlorite. This mineral appears in two forms. In the Triassic rocks especially there occur grains obviously derived from plates of dark mica. In addition to these, irregular grains appear at various horizons in the Devonian, Carboniferous, and "Permian" rocks, and such can only be described as chloritic in character. Mr. Dixon's suggestion that chamosite is of more widespread occurrence than is generally supposed is of interest in this connexion.

Green Garnet. It is not certain how much of the material referred to provisionally as green garnet or spinel may not prove to be merely clear oval plates of a chloritic mineral.

CONCLUSION.

As indicated at the beginning of this communication the writer's aim has been rather to compare and contrast the chief characteristics of the heavy residues from the various arenaceous Midland rocks than to give detailed descriptions of all the minerals seen, or to offer opinions regarding the sources from which the detrital material has been derived. Before attempting the latter the rocks must be investigated over a wider field, with close attention to zonal stratigraphy and the occurrence of the less frequent minerals, but the present paper should serve to convey a general impression concerning the distribution of the more important heavy minerals in the Midland deposits.

Further and more detailed work in each formation should show whether it is possible to assign to each bed in the geological sequence a more or less definite mineral assemblage with a view to correlation where other methods have not proved successful. The opinion is here expressed that the results so far attained tend to indicate that there is no inherent impossibility in the idea, provided, of course, that the limitations of the method are recognized, and due regard paid to local conditions affecting the derivation of material.

Finally, the writer would like to express his thanks to Mr. Wickham King for much help in connexion with the Devonian and "Permian" rocks, to Mr. F. J. Fraser for assistance in the field-work, and to Mr. F. Raw and others for helpful criticism and assistance in obtaining material. The above work was to a large extent undertaken as the result of a suggestion made by Professor P. G H. Boswell, to whom the author is also indebted for various items of information in connexion with the paper. In the revision of the paper the writer has to thank Mr. E. Dixon for much useful advice and criticism. The writer also acknowledges with thanks a grant from the Endowment of Research Fund of the Birmingham Natural History and Philosophical Society towards the cost of the plates illustrating this paper.

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In connexion with the Triassic rocks see also references given in the author's original paper (1).

KEY TO PHOTOMICROGRAPHS OF HEAVY RESIDUES.

FIG.

PLATE IV.

1.—Cambrian quartzite. (Locality No. 12*a*.) × 45. Showing rolled zircon with some magnetite, anatase, and tourmaline.

2.—Silurian (Llandovery) sandstone. (Locality No. 2.) × 37. Showing rolled zircon, magnetite, ilmenite (leucoxene), tourmaline, and anatase.

3.—Carboniferous. (Locality No. 3.) × 45. Showing abundant pyrites with a little zircon and garnet.

4.—Carboniferous. (Locality No. 4.) × 45. Showing zircon, magnetite, worn prismatic apatite and a rounded apatite grain partly surrounded by secondary material, hexagonal in cross section.

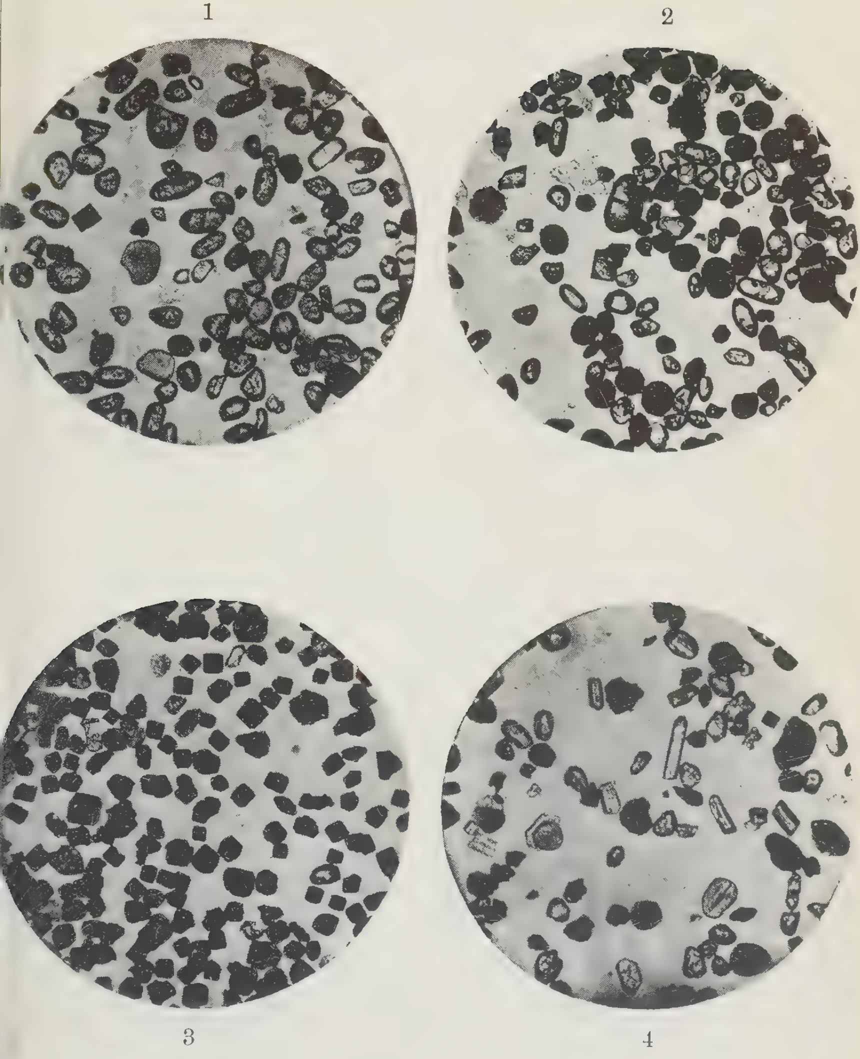
PLATE V.

5.—"Permian" breccia from Sutton Park. (Locality No. 2.) × 45. Showing magnetite, zircon, a little ilmenite and apatite, with a good crystal of barytes.

6.—Triassic (Lower Bunter) sandstone from Habberley. × 34. Showing abundant barytes fragments, with some quartz and a few rolled zircon grains.

7.—Triassic (Upper Bunter) sandstone from Blackwell. × 45. Showing prismatic and rounded apatite with magnetite, a little zircon and some iron-stained quartz.

8.—Triassic sandstone. (Same locality as 7.) × 45. Showing zircon, tourmaline, ilmenite (leucoxene), magnetite, staurolite, and rutile.



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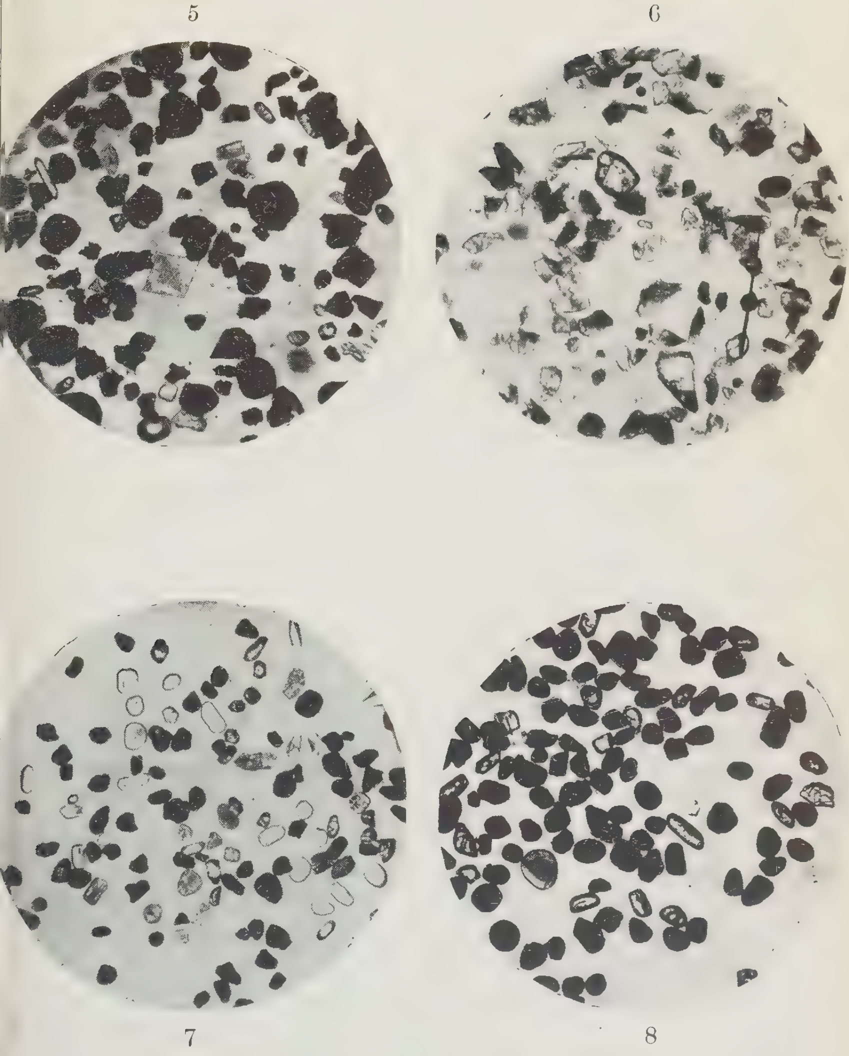
HEAVY MINERAL RESIDUES FROM MIDLAND CAMBRIAN, SILURIAN, AND CARBONIFEROUS ROCKS.

[*To face p. 128.*



avy Mineral Residues from Midland "Permian" and Triassic Rocks.

An Outline of the Geology of South-Western Lleyn.

By C. A. Matley, D.Sc., F.G.S.

A GEOLOGICAL survey of the Pre-Cambrian area of South-Western Lleyn and of some of the Ordovician country to the east of it was made by the present writer between the years 1909 and 1912. An account of the geology of Bardsey Island was published in 1913,[1] but ten years' absence abroad has delayed the description of the rocks of the adjacent mainland. A further absence from Europe will cause additional delay in the presentment of a full account of the district, and it seems desirable that some of the more important results of the survey of this tract of ground should now be placed on record.

The history of geological research in this district together with acknowledgments of the petrological and palaeontological assistance given by friends will be reserved till the full account of the geology is prepared. But it is only right to mention now that Greenly's account of the Mona Complex of Anglesey in the recently published Geological Survey Memoir has been most valuable for the correlation of the corresponding rocks of Lleyn, and that I have had the further advantage of discussing with him in the field, during a visit by him to Lleyn, questions of detailed correlation with the members of the Complex which are developed in Anglesey. I am also indebted to Dr. Greenly for seeing this paper through the press during my absence abroad.

The district to be described is a triangular portion of the Lleyn peninsula. It is bounded on the north-west by the coast-line from Nevin and Trwyn Porth-Dinllaen to Bardsey Sound, a distance of 14½ miles; on the south by the coast between Braich y Pwll and Porth Neigwl, a distance of seven miles; and on the east by a line from Porth Neigwl to Nevin. It falls geologically into two divisions, a north-western tract occupied by Pre-Cambrian rocks with some later intrusions, and a south-eastern tract composed of Ordovician sediments with some spilitic lava-flows and numerous sills and laccolites. The solid geology of much of the area is obscured by thick deposits of glacial drift, which will not be considered in the present communication.

The Pre-Cambrian rocks of this district are an extension of the Mona Complex of Anglesey. It is interesting to note, however, that though they extend so far to the west they are, when considered with reference to the strike, really further to the south-east than even that portion of the Complex which, in the Aethwy region, rises to the surface along the Menai Strait.

Several of the subdivisions which have now been established in Anglesey can be recognized in Lleyn. Acid and basic gneisses occur at Penrhyn Nevin in the north, at Llangwnadl and Carog in the middle of the area, and at several localities, both east and west of

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[1] "The Geology of Bardsey Island": *Q.J.G.S.*, vol. lxix, 1913, pp. 514-33.

Aberdaron, in the south. This gneissic group has been found only in the neighbourhood of the Ordovician boundary. Good crystalline mica-schists agreeing in degree of anamorphism and other characters with Greenly's "Penmynydd Zone of metamorphism" in Anglesey are found to the west of the gneisses and are seen at Penrhyn Nevin, Llangwnadl, Mynydd Ystum, Mynydd Bychestyn, and to the east of Aberdaron. Still further west and forming the greater part of the coast-line are rocks that have undergone comparatively little mineral change. They are mainly gritty phyllites with abundant intercalations of grit, quartzite and limestone, sometimes flaggy, sometimes in thick beds. These strata are usually found in a cataclastic condition with the quartzite and limestone bands, both thick and thin, torn by earth-movement into disconnected lenticles and masses. Intercalated with them is an important development of pillow-lavas (spilites) somewhat variolitic, with lenticles and beds of jasper and limestone, associated with intrusive albite-diabases. These lavas have been affected like the sediments by powerful earth-movements, and are often much folded and sheared, and sometimes converted into green or purple schist, but in a number of exposures they are uncrushed and afford as fine examples of pillow-structure as the similar rocks at Newborough in Anglesey. They are found in greatest force at the headland of Porth Dinllaen and around Edeyrn in the north, around Aberdaron and Mynydd Careg in the south, and near Porth Witlin (where gabbro is found with them) in the centre, but many smaller exposures occur. Rocks of a slaty character with

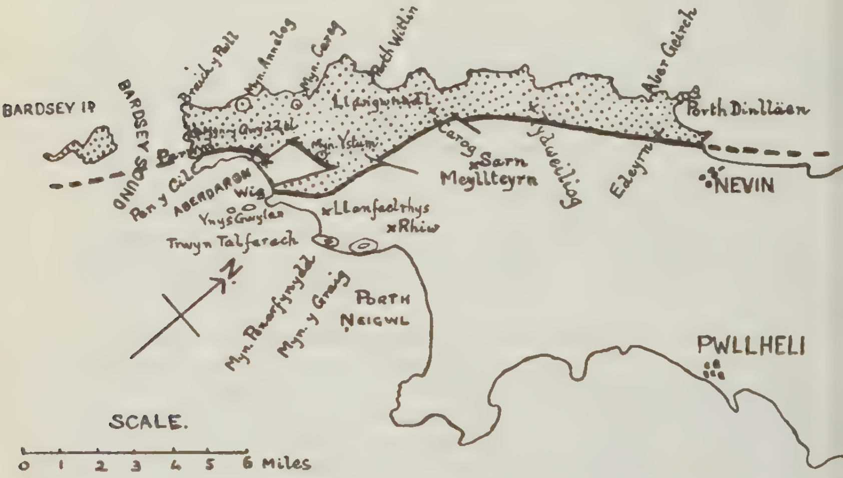

FIG. 1.—Sketch-map of S.W. Lleyn, showing the boundary thrust (indicated by a thick line) between Ordovician and Pre-Cambrian (Mona Complex), the latter being indicated by the dotted area.

some purple zones, much folded and rarely cataclastic, and containing a group of fine-grained flaggy sandstones, lie around Aber Geirch and at a number of other places to the south-west. At the southern end of the peninsula, around Mynydd Annelog and Mynydd y Gwyddel, is the "banded hälleflinta" of Miss Raisin, a fine-grained and cherty-looking dust-rock, several hundred feet in thickness. The limestone and quartzite group with the spilites and jaspers clearly fall into the "Gwna group" of Greenly. The chert-like series seems to be an upward continuation of this group, but its correlation with the Anglesey rocks is still under consideration.

The rocks of the Mona Complex are separated from the Ordovician rocks to the east by a powerful thrust which has driven the former over the latter. The exact course of the thrust-plane is concealed to a great extent by thick drift, but its position can be determined approximately. It runs in a general N.N.E to N.E. direction from the southern end of the peninsula to the sea at Porth Nevin, and probably, continuing beneath the sea, determines the trend of the coast-line from Nevin to Carnarvon, where, near the Castle, rocks thought to belong to the Mona Complex are found to be faulted against Arenig mudstones.[1] The thrust is broken by a number of cross-faults. Around Aberdaron Bay there is a triangular area of Ordovician ground, about 1 mile wide, surrounded (except seawards) by rocks of the Complex. It is suggested that this may be a "window" of over-ridden Ordovician beds, and that the thrust seen at Wig, east of Aberdaron Bay, is a displaced portion of that which is seen at Parwyd, west of the Bay, owing to the downthrow of the thrust-plane by the fault that passes through the small gorge of the River Daron at Pandy Bodwrdda. This explanation implies a shifting of the outcrop of the thrust for a horizontal distance of 1¾ miles.

The Ordovician sediments range from the zone of *Didymograptus extensus* to the top of the zone of *D. bifidus*. The Extensus-beds are argillaceous in part, but contain at least two strong horizons of thick flaggy sandstones, usually fine-grained and streaky. To the south-west and north of Aberdaron the zone includes grit with fine conglomerate and breccia containing fragments of rocks of the Mona Complex in their present state of alteration. The local base of the Arenig series is seen at Parwyd, where a grit with pebbles lies on hornblendic gneisses of the Mona Complex. In the Extensus-zone are beds characterized by *Azygograptus eivionicus*[2] Elles. The Hirundo-zone is best exposed in Nant y Gadwen where it is associated with manganese deposits, as also at Rhiw. The Bifidus-zone has been traced from the south coast at Trwyn Talfarach as far as, and beyond, the village of Sarn Meyllteyrn. The sediments of this zone consist almost wholly of argillaceous mudstones and shales, but among them occur a few spilitic lava-flows, with a little interstitial chert, seen near Sarn and on the western and eastern slopes of Rhiw Mountain.

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[1] G. L. Elles, "Graptolite Zones in the Arenig Rocks of Wales": GEOL. MAG., 1904, pp. 201–3, and Fig. 1. E. Greenly, "The Geology of Anglesey": *Mem. Geol. Surv.*, pp. 382–3.

[2] G. L. Elles, "A New *Azygograptus* from North Wales": GEOL. MAG., 1922, pp. 299–301.

The Ordovician sediments have been much invaded by sills and laccoliths, which have generally been broken by later faulting, so that their outcrops are now disconnected. There are at least two sills in the Extensus-beds, the lower of which, the Pen-y-cil albite-dolerite sill on the west side of Aberdaron Bay, is considered to be the same as that at Pen-dref, north of Aberdaron, and also the same as the Gallt-y-Mor sill that occupies much of the coast between Ynys Gwylan-bach and Llanfaelrhys. A second dolerite sill has been intruded into a higher horizon of the Extensus-zone, into mudstones containing *Azygograptus eivionicus*, and other basic sills occur in and near the Hirundo-zone. The Bifidus-zone has been much invaded by basic sills and laccoliths. Rhiw Mountain consists of a series of sills separated by baked sediments and spilites and capped by a hornblende-dolerite laccolith. Farther south are the laccoliths of Mynydd y Graig and Mynydd Penarfynydd composed of hornblende-dolerite and hornblende-picrite.

Farther north occurs the Sarn granite, which has been injected into Ordovician strata, probably in the form of a laccolith. Its western boundary, though obscured by drift, seems to be the thrust-plane that has brought up the gneisses and schists of the Mona Complex, and its eastern boundary is broken and shifted by faults. The horizon into which it was intruded may be in, and cannot be far below, the Bifidus-zone, as the zonal fossil occurs between the two uppermost of three dolerite sills that lie in the strata resting on the granite.

Basic dykes are conspicuously abundant in the tract occupied by the Complex along and near the coast from Porth Dinllaen to Bardsey Sound. More than 120 have been mapped, but they have not yet been petrologically examined. Many of them will probably be found to possess the characters of Tertiary dykes, but a few are certainly of earlier age, as they have been affected by the Palaeozoic thrusting. Dyke-rocks are rare in the Ordovician ground, but some basic dykes have invaded the Sarn granite.

In conclusion, it may be mentioned that the geological study of this district fully confirms Greenly's views as to the antiquity of the chief structures in the rocks of the Mona Complex and the relatively minor effect produced on those rocks by post-Ordovician-movements.

A Note on the Petrographical Characters of some Rocks from the Northern Range of Trinidad.

By John Parkinson, Sc.D., F.G.S.

In 1907 Mr. E. H. Cunningham Craig's Report[1] on the "Metamorphic Rocks of Trinidad" was published, containing a general description of the structure of and the beds composing the Northern Range of the Island, and this note is accordingly intended merely to call attention to the petrographical characters of some of these altered sediments included in the Caribbian Series[2] of Wall and Sawkins, and by far the oldest rocks in the island.

As regards distribution, they are confined to the Northern Range; a deeply incised, sharply rising ridge, bounded on the north by the Atlantic, on the south by the alluvium of an old sea-floor, and continuous from east to west across the island. The range is linked to the Venezuelan coast by a few small islands separated from each other, Trinidad and the mainland by narrow straits.

A brief description without detail of the oldest rocks of the Caribbian Range in Venezuela has been given by Cortese.[3] These, his "Filladi (Arcaico) scisti lucenti grantifera", he shows in a diagrammatic section as dipping to the north, overlain with a marked unconformity by a crystalline limestone which he denotes as "? (Trias o Cambro-Siluriano) ?" On the southern side, a fault separates these beds from a southerly dipping series consisting of Turonian limestone, Eocene marls and Oligocene sandstone. In Siever's map of Trinidad and Venezuela[4] as far south as the Orinoco he draws the continuation of the rocks of the Northern Range, his "Archaisches Gebirge, Krystallinische Schiefer, Gneis", as a westerly running belt through Carúpano and Caracas to Puerto Cabello and thence south-west through Trujillo to San Cristobal.

It is to be hoped that some of the geologists now present in Venezuela will find opportunity to throw light on this important part of the sub-continent.

The continuity of the range is broken between Cumaná and Caracas by a bay infilled with Quaternary and Tertiary rocks, so as to fall into two parts. These are the eastern and western areas of Cortese, of which the former, wherein phyllites predominate and mica schists are less common than in the latter, is the direct continuation of the Northern Range of Trinidad. A specimen of these rocks from near Cumaná given me by Mr. C. B. Williams, formerly Government Entomologist, is indistinguishable from those of Trinidad. According to Cortese, the rocks from the neighbourhood of Carúpano (the eastern area) are characteristic phyllites, micaceous, lustrous, grey and bluish schists, weathering to a red colour, locally greenish and steatitic, the whole cut by quartz veins. One instance of a true mica-schist is given. From the neighbourhood of Cumaná (eastern area) the rocks are sometimes garnetiferous. The specimens from Trinidad, one from the path leading down from Tucutche, the majority of the others from the recently constructed road on the northern side of Port of Spain, are in some cases microcrystalline quartz-calc-schists, fissile to slabby in habit, of dull brown or grey colour (Fig. 1), the planes of sedimentation glistening with filmy white mica; and in others laminated or finely bedded rocks, between slates and phyllites, containing carbonaceous dust in varying proportion and needles of rutile with varying amounts of mica and chlorite.

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[1] Council Paper No. 76 of 1907.

[2] *Report on the Geology of Trinidad*, London, 1860, p. 13. See also G. P. Wall, *Q.J.G.S.*, 1860, xvi, p. 463.

[3] *Boll. Soc. Geol. Ital.*, 1901, xx, p. 447.

[4] *Pet. Mitt.*, xlii, 1896, p. 125, pl. x. Reproduced in *La Face de la Terre*, t. 3, pie. 3, p. 1295. See also Dalton, Geol. Mag., 1912, p. 203.

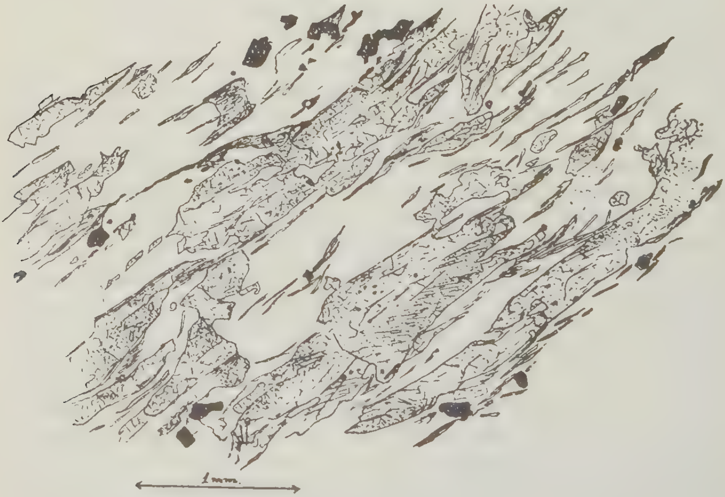

FIG. 1.—Micro-section of quartz-calc-schist; road north of Port of Spain, Trinidad. × 21 diameters.

Road sections show that the rocks have been much disturbed; they are commonly strongly folded and contorted.

In none of the slides is there sign of the original outline of the quartz grains, which are as a rule fairly uniform in size throughout the section; they are not large and uncommonly in a cryptocrystalline condition. They show interlocking outlines, but not, as observed, the pseudopodia-like apophyses seen in some quartzites.

In one specimen a few grains of acid felspar were noticed, water-clear or slightly dusty, and it is possible that this mineral may exist more commonly than a preliminary examination would suggest.

The rock from the slope of Tucutche contained about seveneighths carbonate to one-eighth quartz, the latter forming little nests or strings of grains between the crystals of the dominant mineral. In other slides quartz predominates. The carbonate is calcite in, at least, most cases, but in order to determine if dolomite were present, Lemberg's solution was applied to two sections of the more typical rocks. No effect was produced under less than 12 minutes' exposure, when it was found that the majority of the carbonate grains were stained. A few, however, had either not taken up the stain, or had had it removed by washing, and a partial analysis was made of one specimen. The result was calcium carbonate, 44·35 per cent; magnesium carbonate, 0·79 per cent. The proportion of $CaCO_3 : MgCO_3$ is 56·14 : 1. Dolomite is therefore absent.

In regard to accessory constituents, magnetite in idiomorphic crystals or as dust is typical.

In these calc-microschists extremely fine needles of a colourless or faintly yellow mineral, which is believed to be rutile, occur locally in clusters, but without assuming the considerable importance they do in other non-calcareous rocks, where they form dense felts producing the effect under a low power objective of a semi-translucent cloud of an iron-grey colour.

The segregation of the rutile felt into laminæ is doubtless a result of original deposition.

One section, cut through a sharp fold, showed a double band of rutile needles separated by a lamina of quartz. Round this fold the individual crystals of the former mineral are arranged in all directions, but show a marked tendency to retain that of the original bedding, though at the apex the needles constituting one band have grown tangentially. It is clear that the needles are later than the movement, for they are not broken.

Cryptocrystalline quartz in the centre of part of the fold shows the rock could not quite recover from the effects of crush. Films of white mica occur, but are rare; their place is taken by flakes of a pale green faintly pleochroic chlorite, which in places constitutes a quarter to half of the section. The direction of orientation of the two minerals is unaffected by the folding. The carbonate, restricted to one lamina, occurs in rhombs, singly, or in small groups of crystals. This may be dolomite.

In regard to the production of the rutile needles, if they are assumed to be derived from the decomposition of biotite, the alumina and magnesia would contribute to the formation of the chlorite and the potash perhaps to the few flakes of white mica, the iron being contained either in the chlorite or crystallizing separately as magnetite.

Graphite-slates or phyllites have been known from the Northern Range for long, and an example of these is a dark iron-grey finely laminated or foliaceous rock, showing minute corrugations of the surface as the result of pressure.

In a thin section grey flocculent aggregations, slightly elongated in the direction of foliation, are the distinctive feature. These contain a large number of rutile needles, not conspicuous for a single orientation, but having a marked association with the carbonaceous material. Reflected light shows the opaque material to consist of thin dull black flakes of what is assumed to be graphite, and an indefinite substance with semi-metallic lustre probably a mixture of iron and material which is presumably amorphous carbon. White mica flakes are rather common, but chlorite does not occur and the quartz is very fine-grained, almost in the cryptocrystalline state. It is suggested that a mixture of ilmenite and carbonaceous material has given rise, the former to rutile and disseminated iron, the latter to some proportion of graphite dependent on the degree of metamorphism.

In these slides the only accessory minerals noticed were a few minute prisms of brown tourmaline and grains of zircon.

In some cases the rock is of very fine grain (Arime–Blanchisseuse Road), quartz is rare, and occurs in minute strings or nests, the slide is almost opaque owing to carbonaceous and some ferruginous matter, the bulk of the slate being made up of films of strongly orientated mica. In others a highly altered mineral, showing as rusty spots (about 0·15 mm. across), forms occasionally nearly a quarter of the section.

They have well-marked rhombic outlines and are probably a ferriferous carbonate altering to limonite.

REVIEWS.

THE GEOLOGY OF YORKSHIRE. By P. F. KENDALL, F.R.S., M.Sc., and H. E. WROOT. pp. xxii + 995, with many illustrations. Printed for the Authors, 1924, and to be obtained only from them. Price 16*s.* post free, or in two volumes 17*s.* 6*d.*

YORKSHIRE is a large place, larger than is often realized by the mere Southerner, who fails to grasp the fact that two places in the county may be a hundred miles apart. Also it is very varied both topographically and geologically, comprising a large number of different stratified formations, and with an exceedingly complex history. Consequently the writing of a complete "Geology of Yorkshire" is a stupendous task. It is, therefore, not altogether surprising if the volume before us shows a certain amount of inequality: while most of it is admirable, there is room for criticism in some sections. If some of these points are noted first, it is in no carping mood, or spirit of detraction, but merely to clear the ground, and this procedure is really justified by the fact that the passages to which exception may be taken are mainly in the earliest chapters.

In the first place the present reviewer can hardly be expected to agree with the writers' apparent inclination to endorse the view of Mr. J. F. N. Green as to the age of the Ingleton series, a view which from internal evidence in his paper appears to be founded only on an examination of a section or sections near Ingleton. The evidence afforded by the valley of Chapel-le-Dale is inconclusive and actually misleading, and it is difficult to believe that anyone who had seen the great excavation at Mr. John Delaney's lime works at Horton-in-Ribblesdale, or the section in Dowk Gill, to the east of the same village, could have come to such a conclusion as Mr. Green put forward, in view of the enormous difference in structure and degree of metamorphism between the Ingletonian slates and grits and the highly fossiliferous Ashgillian rocks of the same area. This, however, can in no way be imputed for blame to Messrs. Kendall and Wroot, who express themselves somewhat cautiously on this point.

A slight misunderstanding as to the mutual bearings of the work of Professor Marr and Dr. Elles on the Lower Palaeozoic rocks has already been dealt with by the authors in our correspondence columns, so no more need be said on this point. Again, on page 36, it is said that "Dr. Marr has interpreted the Howgill Fells as a series of three domes . . . etc." What Professor Marr really said, with perfect accuracy, was that the small Ordovician inliers on the eastern side of the Howgills show this structure, a very different matter. It is as if a description of a postage stamp had been interpreted as referring to the whole envelope. Altogether, in the first four chapters there are a good many minor inaccuracies, which need not be further particularized. These chapters only amount to 36 pages out of 995, and the Lower Palaeozoic rocks do not really cover much ground in Yorkshire.

When we come to the later formations the authors are on firm ground, and the book provides fascinating reading. It is doubtful whether it will be most enjoyed by those to whom the facts are familiar, or by those to whom it will come as a revelation, if there are any such. In catering for a wide class of readers, the authors have provided here and there disquisitions on certain general principles of geology which may be superfluous for experts, but they cannot fail to give to the educated, non-geological reader a good grasp of the subject, sufficient to enable him to appreciate the points that follow. It is fairly apparent that most of the actual writing has been done by Mr. Wroot, but the ideas expounded are those of Professor Kendall, who is, of course, the acknowledged authority on many questions of Yorkshire geology. Nevertheless, due attention is paid to the views of others when opinions differ.

A very full account is given of the wonderful underground geology of the limestone country of West Yorkshire, an unrivalled example of its type, which has been the scene of so many daring explorations, and many beautiful pictures are here reproduced of scenes both above and under ground, while the chapters on the Millstone Grit and the Coal-measures are masterpieces of lucid exposition. When dealing with mining in Yorkshire in early days it is pleasing to note that due credit is given to the monastic orders, and especially to the Cistercians, for their pioneer work in the revival of industries which after Roman times had languished or died out as a result of the "frightfulness" of Teutonic invasions.

A long chapter is devoted to the post-Carboniferous earth-movements and their accompanying fractures. Some diagrams showing all the known faults of the Pennine region are particularly striking, as bringing out clearly the dominating influence of the old Charnian folding in determining the direction of later fractures. In the Yorks-Derby-Notts coalfield practically all the faults show the Charnian or Caledonian directions, and the first-named is on the whole the more conspicuous: between Bradford and Sheffield this relation is particularly clear.

The account of the Permian rocks is remarkably good, but it might perhaps be thought that the section devoted to the Mesozoic rocks is rather compressed in comparison with the space devoted to the later formations. Since there are no known Tertiary deposits in Yorkshire the account of this period is devoted to an account of the development of the Yorkshire rivers, a classical subject on which there is no need to enlarge. It is doubtful even now whether most geologists realize the extraordinary character of the drainage of East Yorkshire; that is, of the great area east of the Vale of York. The original drainage system of this area is, however, so masked by changes during the Glacial period that we shall probably never know what really happened originally to the lower courses of some of the West Yorkshire rivers. The present writer believes that the old Tees did flow through the present Esk valley; the size and character of this valley above Lealholm is entirely out of scale with the lower drift-blocked portion from Crunkley Gill to the sea, and must have been formed by a big river. Also some river, Swale or Ure, or both, must have run past Gilling, through the rift-valley, and the Vale of Pickering, to the sea near Filey, but it is impossible to believe that any river of this system ever crossed the moors to the New Cut at Scalby, as has been suggested by an earlier writer: if a Pennine river ever did follow this line it must have been so far above the present surface that no relation to present topography could be established.

As would naturally be expected, we have here an admirable exposition of Professor Kendall's great work on glacier-lakes, both in the Cleveland Hills and elsewhere, and that of his school of followers. It may perhaps here be noted that even in the reviewer's lifetime the meaning of the name Cleveland has been enormously extended; forty years ago it was never applied to anything south of the Esk, and the original eastern boundary seems to have run from the sea at Sandsend to some point near Grosmont or Egton Bridge. Whitby Strand was distinctly understood not to be in Cleveland. Now, however, the name is applied by some geologists to the whole moorland area as far south as the Vale of Pickering. The area between this and the Esk was formerly known as Blackmoor, or Blackamoor, a name which is now probably extinct in local speech, though the reviewer has heard the town in Ryedale called Helmsley Blackamoor, to distinguish it from Gate Helmsley, near York. It is satisfactory to find that this ancient name for the moorland area is noted in this book (page 491).

Three chapters are devoted to post-Glacial history, and deal with many matters of interest; as is well known, Yorkshire is rich in barrows and other evidences of prehistoric and later cultures, including cave deposits and possibly even pile-dwellings. Another matter of great interest, on which Mr. Sheppard has done much admirable work, is the changes in the position of the coastline and the shores of the Humber: of this an account is given, based on his researches. The story of the lost towns of Holderness involves many romantic episodes, including the landing of two successful claimants for the English crown at the vanished port of Ravenser Odd.

Space will not allow of a reference to any more of the numberless points of interest raised by this book, or to the many illustrations. These are not numbered, but a rough count gives about 200, including portraits of many Yorkshire geologists.

Part II, amounting to about 60 pages, gives an account of the geology of Yorkshire as it can be seen from the train, with some interesting notes on the early history of the railways, with brief sketches of the personalities of some of their pioneers. It is perhaps rather surprising that the journey from Malton to Whitby, in many ways the most interesting of all, is not described. Part III, of some 230 pages, is devoted to directions for carrying out geological excursions in Yorkshire. This is an admirable feature. As the book itself is uncomfortably heavy and cumbrous to carry, and is likewise cheap, geologists may be recommended to buy a second copy, to cut out the excursion part, and bind it up separately. This point of cumbrousness was noted by many early readers, and the authors have now wisely decided to issue it in two volumes at a slightly enhanced price. It is perhaps regrettable that a book on Yorkshire geology should be printed in Vienna, but it is doubtless this fact alone that makes it possible to sell it at such an abnormally low price; in conclusion, we may express the hope that the enterprise of the authors in undertaking to be their own publishers may be duly rewarded by the extensive sales that such a book deserves. The size of Yorkshire, as mentioned in the first paragraph, and the size of the book, must together serve as excuses for the abnormal length of this review.

R. H. RASTALL.

LA GÉOLOGIE SISMOLOGIQUE. By F. DE MONTESSUS DE BALLORE. Paris, 1924.

LESS than twenty years ago, M. de Montessus de Ballore gave us two important volumes on seismology and, just before his death, early in 1923, he finished the manuscript of a third. The first and most original, *Géographie Séismologique* (1906), dealt with the distribution of earthquakes over the globe; the second, *La Science Séismologique* (1907), is a treatise on seismology; the third is mainly concerned with those earthquakes, usually great earthquakes, which produce perceptible displacements of the earth's crust. As Montessus shows, these are much more numerous than is generally supposed.

The book is divided into five parts. In the first we have the classification of earthquakes, the second treats of the earthquakes just referred to, the third of volcanic and rock-fall earthquakes, the fourth of the secondary effects of great earthquakes, and the last of some miscellaneous problems of geological interest.

The usual classification of earthquakes, due to Hoernes in 1878, is that into tectonic, volcanic, and rock-fall earthquakes. Montessus makes two main classes—glyptogenic or geological, in which crust-displacements of geological importance occur, and external dynamical, including both volcanic and rock-fall earthquakes. Glyptogenic earthquakes are subdivided into epeirogenic, tectonic, and epeirogenic and tectonic, according as the displacements are vertical, horizontal, or both vertical and horizontal. Montessus thus limits to one sub-class the term *tectonic* devised and generally used to cover all three sub-classes. And he has no place in his classification for the most numerous of all earthquakes, those which are neither volcanic nor rock-fall earthquakes and yet do not produce perceptible displacements of the earth's crust.

The classification, however, affects but slightly the main current of the book. Like the earlier works, the third volume is the product of a wide course of reading, and few men have had Montessus' acquaintance with the whole literature of seismology. To geologists the book will be invaluable. Those who have not time to read the whole can obtain a good knowledge of the subject by studying one or two examples of each class—say, the New Madrid earthquakes of 1811–12 or the Assam earthquake of 1897 as epeirogenic earthquakes, the Californian earthquake of 1906 or the Owen's Valley earthquake of 1872 as tectonic earthquakes, the Mino-Owari earthquake of 1891 or the Yakutat Bay earthquakes of 1899 as epeirogenic and tectonic earthquakes, the Hawaiian earthquake of 1868 or the Ischian earthquake of 1883 as volcanic earthquakes, and the Kingston earthquake of 1907 or the Messina earthquake of 1908 as earthquakes due to the isostatic readjustment of alluvial plains or the subsidence of coasts and submarine talus. One can imagine the excellent use he would have made of the Japanese earthquake of 1923 under the latter heading, if he had lived to know of the results.

Some other chapters will also appeal to geologists, especially those on avalanches, the effects of earthquakes on glaciers, the migration of epicentres, and the geographical distribution of earthquakes. The biographical notice of the author and the list of his long series of memoirs by M. Armand Renier add to the interest and value of the book. The selection of the illustrations and the correction of the proofs is the work of others, and both have been well and carefully done.

C. D.

CAMBRIDGE UNIVERSITY EXAMINATION PAPERS. Geological maps reprinted from the Natural Sciences Tripos. Parts I and II, 1911–24. pp. 24. Camb. Univ. Press. Price 1*s*.

THIS reprint of 22 geological maps set during recent years in the Natural Sciences Tripos will no doubt be found of considerable convenience to students of geology who wish to practise reading maps of a problem nature. No letter press has been added beyond giving the date when each map was set, with the result that the cost of each map works out at little over one halfpenny.

REPORTS AND PROCEEDINGS.

MINERALOGICAL SOCIETY.

20th January.

K. Yardley: An X-ray examination of calcium formate. The orthorhombic bipyramidal unit cell contains eight asymmetric molecules. The dimensions are $a = 10{\cdot}19$ Å, $b = 13{\cdot}41$ Å, $c = 6{\cdot}27$ Å. The structure is founded on the Bravais lattice Γ_o and belongs to the space group Q_h^5.

John Parry and Dr. F. E. Wright: Afwillite, a new hydrous calcium silicate from Dutoitspan mine, Kimberley, South Africa. This mineral was found by Mr. A. F. Williams as large water-clear crystals. These are monoclinic. Analyses give the formula $3CaO.2SiO_2.3H_2O$ or $2H_2CaSiO_4.Ca(OH)_2$. It has a slight alkaline reaction and is completely decomposed by dilute hydrochloric acid. Optical and crystallographic data are given in detail.

Professor P. N. Chirvinsky: Tyuyamunite from the Tyuya-Muyun radium mine in Fergana. A review is given of the literature on the copper, vanadium, and uranium ores at this locality. The mineral tyuyamunite, $CaO.2UO_3.V_2O_5.mH_2O$, is related to carnotite, having calcium in place of potassium. The microscopical characters of the minute orthorhombic crystals are described.

Dr. L. J. Spencer: International agreement in mineralogical and crystallographical nomenclature. With a small amount of "give and take" in different countries much greater uniformity could be attained for mineral names. For international purposes the correct spelling of the printed word is of more importance than the correct pronunciation. There is no necessity to provide well-established mineral names with the termination *ite*. The Millerian notation for crystal planes is the best for international use. The principal optical directions are conveniently given by α, β, γ, corresponding with the three principal indices of refraction.

OBITUARY.

David Woolacott.

Geology in the North-East of England has suffered a serious loss by the untimely death, on 4th August last, of Dr. David Woolacott, at the early age of 52. Born in Sunderland on 1st July, 1872, and losing his father only one year later, he was in due course enabled by his mother's foresight and devotion to proceed to Armstrong College, where he studied geology under Lebour, and graduated in 1895. After a brief period of school teaching he returned to his own College as demonstrator, and became successively Lecturer and Reader in Geology. He was elected a Fellow of the Geological Society in 1897 and in 1920 was awarded the Murchison Fund in recognition of upwards of twenty years' assiduous geological work.

Woolacott was a true Northcountryman in his devotion to his native county, and, while he travelled widely in pursuit of geological knowledge, his original work was almost wholly given to the geological problems of Northumberland and Durham, concerning which he published upwards of twenty original papers. His attention was at first largely devoted to the Pleistocene geology of the area, and a large mass of work was collected into the paper on the "Superficial Deposits and pre-Glacial Valleys of the Northumberland and Durham Coalfield" (*Q.J.G.S.*, 1905), in which the leading features of the pre-Glacial surface was established. He studied with unflagging zeal every aspect of the local geology, but he will be remembered among his fellow-workers especially for his insistence on the importance of earth-movement as a leading factor in the production of the structural features of the rocks of the district, and in particular of the remarkable brecciation of the Magnesian Limestone. Some geologists will hesitate in accepting all the conclusions, but all will agree in their gratitude for the way in which the amazing structure of the rocks was demonstrated to them.

Fortunately, Dr. Woolacott published quite recently in this Magazine two papers ("The Magnesian Limestone of Durham," Geol. Mag., Vol. LVI, 1919, pp. 452, 485; and "The Interglacial Problem and the Glacial and Pre-glacial Sequence in Northumberland and Durham," Geol. Mag., Vol. LVIII, 1921, pp. 21, 60), in which he summarized his views on two of the main themes which had engaged his attention. It had been his intention to continue a series of such papers, which together would have constituted a complete account of the local geology, with discussions of its wider significance. Only those who had personal knowledge of the fund of information he had gathered can appreciate the loss which the cutting short of this project entails.

Woolacott was a true enthusiast, with the deepest love for his subject, and so, like all enthusiasts, a good teacher. He is remembered with affection alike by his colleagues and by the many students who passed through his hands.

G. H.

CORRESPONDENCE.

MR. WARREN'S VIEWS ON PLEISTOCENE CLASSIFICATIONS.

The *raison d'être* for Mr. Warren's Presidential Address on "Pleistocene Classifications" delivered recently to the Geologists' Association (*Proc. Geol. Assoc.*, 1924, part iv), would appear to be revealed in the following statement (p. 265): "On the present occasion I propose to invert the usual order, and to take the human culture stages of France as the basis of the time scale, and to refer the ice ages to them instead of vice versa. This is being done as an experiment, in order to see how matters will work out on this basis."

Though it is not clear what was in Mr. Warren's mind when he was arriving at this decision, yet the result of this so-called experiment manifests itself in the form of a " Table of Comparative Pleistocene Classifications "—which, for sterile and chaotic complexity, will, it is to be hoped, for ever remain unrivalled.

While the exact meaning of Mr. Warren's thesis has eluded me, this paper contains a number of statements which are unsupported by evidence, and, as may be seen by reference to the original publications dealing with these matters, are inaccurate. Some of these misleading assertions are given below :—

1. p. 267. That the " Ipswich evidences " showing that the Upper Chalky Boulder Clay is of Mousterian age " have been misread ".

2. p. 271. That the Boulder Clay overlying the Mousterian brickearth at High Lodge, Suffolk, " may be a redistribution or trail " of the Boulder Clay underlying this brickearth.

3. p. 273. That a " level " plain can exhibit any slope " appreciable " or otherwise.

4. p. 274. That, at West Runton, near Cromer, " The cliff-section here shows a palaeolithic river gravel overlying the glacial sands and contorted drift."

5. p. 277. That the early Chellean flint implements found upon the foreshore at Cromer " have not been washed out of the Forest Bed, but belong exclusively to the beach ".

6. p. 277. That " the palaeolith from the beach at Palling, is clearly derived from one of the river-gravels which overlie the glacial deposits of the Norfolk coast ".

It is clear that Mr. Warren is determined at all costs to attempt to maintain his opinions upon the question of the antiquity of man and his relationships to the glacial deposits of East Anglia. In order to do this it is only necessary, as he appears to believe, persistently to deny the validity of any discoveries that militate against his views and to put forward, without hesitation, baseless arguments in opposition to these discoveries. That this is true is shown firstly by his audacious suggestion, unsupported by one tittle of evidence, and in flat contradiction to all we know of existing primitive people, that (pp. 277–8) the earliest representatives of the human race did not use stone implements of any kind, and secondly by his equally audacious, and again entirely unsupported claim, made at a meeting of the Royal Anthropological Institute recently, that the early Chellean hand axes recovered by me from the base of the Cromer Forest Bed are of natural origin. Mr. Warren is living in the " dark ages " of prehistoric archaeology. He still holds to the belief that the earliest vestiges of man in England are referable to post-Upper Chalky Boulder Clay times, and, as would be expected, and as his latest utterances show, he is finding it increasingly difficult to hold what is, without doubt, an altogether impossible position.

J. Reid Moir.